CERES_CldTypHist_Ed4A

Data Quality Summary (6/1/2017)

Investigation: **CERES**
Data Product: CldTypHist

Data Set: **Terra+Aqua+GEO**

Data Set Version: **Edition4A**

Subsetting Tool Availability: http://ceres.larc.nasa.gov

The purpose of this document is to inform users of the accuracy of this data product as determined by the CERES Science Team. The document summarizes key validation results, provides cautions where users might easily misinterpret the data, provides links to further information about the data product, algorithms, and accuracy, and gives information about planned data improvements. This document also automates registration in order to keep users informed of new validation results, cautions, or improved data sets as they become available.

This document is a high-level summary and represents the minimum information needed by scientific users of this data product. It is strongly suggested that authors, researchers, and reviewers of research papers re-check this document for the latest status before publication of any scientific papers using this data product.

Note to Users:
• CERES CldTypHist Ed4A replaces the CERES-ISCCP-D2like Ed3A product

NOTE: To navigate the document, use the Adobe Reader bookmarks view option. Select "View" "Navigation Panels" "Bookmarks".

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1.0 Nature of the CERES_CldTypHist_Ed4A Products

The CldTypHist Ed4A product replaces the CERES ISCCP-D2like Ed3A products. The CldTypHist Ed4A product reformats the CERES-SYN1deg-hour/day/month Ed4A Terra and Aqua MODIS and 1-hourly geostationary (GEO) Ed4A cloud properties into the same cloud types incoporated in the NASA GISS ISCCP-D2 cloud products. The cloud properties are averaged into 3 cloud top pressure (PC) and 3 optical depth (tau) bins. The 9 PC-tau cloud types are shown in Figure 1-1. The 9 cloud types are further sub-divided into liquid and ice clouds in the CldTypHist product. The CldTypHist Ed4A product can be used in all ISCCP-D2 applications, such as GCM validation and other climate modeling studies. Unlike the 3-hourly ISCCP-D2 data the CldTypHist product is based on hourly cloud observations, which are suited for regional diurnal cycle and process studies. The CldTypHist product has a higher 1° lat/lon grid spatial resolution than the GISS ISCCP-D2 the 2.5° equal area product. Also the CldTypHist product includes additional cloud parameters than the ISCCP D2 product, based on MODIS and GEO multiple channel cloud retrievals.

Note: The new CldTypHist Ed4A product name will remove the confusion associated with the CERES ISCCP-D2like product name, which was originally named in order to convey to the user that the CERES MODIS and GEO cloud properties were averaged into cloud types. The CERES ISCCP-D2like product was not in any way a coordinated effort or associated with the NASA GISS ISCCP project.

The SYN1deg Ed4A was a CERES product designed to provide the highest temporal resolution TOA and surface flux dataset by incorporating hourly GEO imager data and by taking advantage of the enhanced GEO imager capabilities to improve the cloud property retrievals, computed surface fluxes, and GEO derived TOA fluxes. The SYN1deg Ed4A should not be used to infer long-term trends of clouds or fluxes. **Users should be aware that when ever a GEO domain is crossed, whether in time or space, a slight change in mean cloud property values should be expected.** Users are advised to use the EBAF-TOA and EBAF-Surface products to determine the long-term flux natural variability and temporal trending. The EBAF-TOA Ed4.0 product provides monthly cloud properties suited for EBAF flux analysis, by combining Terra and Aqua-MODIS cloud properties. The Terra or Aqua SSF1deg Ed4A MODIS retrieved cloud properties are of climate quality and can be used to determine long term regiobal cloud trends, however, they do not encompass the entire diurnal cycle.

The SYN1deg Ed4A and CldTypHist Ed4A products were designed for short term and regional diurnal process studies, for example field campiagns and intensive observation periods (IOPs). For Ed4A the CERES project has taken advantage of the next generation GEO imager capabilities rather than rely on a 1st generation GEO cloud retreivals. The intent was to improve the computed surface flux using the enhanced cloud properties. The surface flux computation algorithm was modified as a function of GEO imager characteristics in order to provide consistent surface fluxes across the MODIS and 16 GEO imagers. This is the first attempt for the CERES project to apply a more MODIS like cloud retrieval algorithm across the GEO satellites, to achieve more uniform MODIS and GEO clouds. The individual GEO cloud retrieval algorithms were optimized using a few test months. The new GEO cloud retrievals take advantage of the additional channels, which were not utilized in the visible and IR-only CERES ISCCP-D2like retrieval code for Ed3A. However, the many GEO imager capability differences such as number of channels, spectral response, and image quality, make retrieving uniform cloud properties across the GEO constellation more challenging. Improvements in GEO cloud retrieval consistency as well as improved computed surface fluxes is planned for Edition 5.

In general the Ed3A GEO domain cloud properties are more temporally stable then for Ed4A. However, the Ed4A clouds are probably more in line with MODIS, especially at night, in order to compute more accurate surface fluxes. The current plan for Edition 5 is to provide uniform cloud properties across GEO domains for the full CERES record and to provide a short term dataset that takes advantage of full constellation of 3rd generation GEOs and 2nd generation Metoesats, that have channels similar to MODIS, in order to retrieve near MODIS-like clouds, merged with all available MODIS and VIIRS clouds onboard, Terra, Aqua, NPP, JPSS-1 beginning in 2019.

1.1 CldTypHist Algorithm

The CldTypHist Ed4A product provides Terra-MODIS, Aqua-MODIS, and 1-hourly GEO cloud property retrievals that have been spatially gridded into 1°-regions and averaged into monthly 1-hourly and monthly time scales, where the cloud properties have been stratified by optical depth and cloud pressure levels similar to the ISCCP D2 product (Rossow and Schiffer 1991). The MODIS cloud properties are not the official Goddard DAAC MODIS MOD0x or MYD0x cloud retrievals, but are based on the CERES cloud working group Ed4A retrievals (Minnis et al 2011), which are available on the SSF level-2 and SSF1deg-hour/day/month Edition 4A products. CERES CldTypHist product utilizes GEO cloud retrievals within 60° S and 60° N in order to provide diurnal coverage between the Aqua and Terra observations. Figure 1-2 identifies the GEO satellites used in the CERES record. The 1st generation GEO cloud properties are retrieved from a two channel (2-ch) algorithm using only the visible and IR bands (Minnis et al. 1995) similar to the ISCCP-D2 cloud algorithm. GOES 2nd generation 5-channel imagers include the 0.65µm, 3.9µm, 6.7µm, and 11µm channels. Beginning with GOES-12 the 12µm channel was replaced with the 13.3µm channel. The GOES 8-11 cloud retreivals are based on all 5-channels (5-ch-12) as well as the GOES-12-15 (5-ch-13.3) The Meteosat 8-10 and Himawari-8 are retreived from multiple channels (M-ch) dependent on the GEO imager channel configuration. The GEO M-ch cloud retrieval is similar to the CERES MODIS cloud retrieval algorithm except that it utilizes fewer channels subject to the number of available GEO imager channels (See Table 1-1). All M/5-ch cloud retrievals are based on the daytime VISST and night time SIST algorithm (Minnis et al. 2011a).

The instantaneous 1-km (sub-sampled at 2-km) pixel level MODIS cloud properties are averaged within a CERES 20-km footprint and stratified into two possible dynamic cloud layers (Geier et al 2003 Fig. 4-10). All of the CERES sub-footprint layers for a satellite overpass within a 1° region are assigned to a cloud type. If there are multiple footprints having the same cloud type, the instantaneous sub-footprint cloud properties are averaged within the 1° region. The GEO M/5-ch clouds are retrieved at the 4-km (sub-sampled at 8-km) pixel-level. The instantaneous GEO M/5-ch pixel level clouds are then averaged into their respective 3x3 Pc-tau cloud types within a 1° region. The daytime GEO 2-ch are first averaged into the same SYN1deg static 4-layers in the CERES Ed4A processing environment. In order to back out the cloud optical depth for each of the layered cloud properties, the log and linear optical depth are used to compute the optical depth distribution using a gamma distribution (Kato et al. 2005). The integration of the PDF within the optical depth range for the given bin determines the optical depth for the bin (See Figure 1-3).

The CldTypHist Ed4A cloud parameters are listed in Table 1-2. The CldTypHist Ed4A parameters contain all of the ISCCP D2 cloud parameters and provide additional parameters, which include cloud base/top pressure/height/temperature, IR emissivity, and particle size (See Table 1-2). The MODIS and GEO M/5-ch retrievals provide all the parameters for both daytime and nightime measurements. The daytime GEO 2-ch assumes a static particle size of 10μm and 30μm radii for liquid and ice clouds, respectively. The daytime GEO 2-ch retrievals use a cloud effective temperature threshold of 253°K to discriminate between liquid and ice phases. The CldTypHist product computes the IWP and LWP from the optical depth and particle size for both GEO and MODIS clouds. The GEO 2-ch cloud retrievals can not be utilized at night, since they do not have an associated optical depth. The CldTypHist Ed4A product does not temporally interpolate cloud properties between observed clouds as does the SYN1deg product in order to facilitate hourly surface flux radiative transfer model computations. Temporal interpolation between differing cloud types may result in unrealistic PC-tau types and may negatively impact the CldTypHist Ed4A monthly cloud properties.

The CldTypHist monthly hourly cloud properties are averaged from all of the daily measurements for each hour. The cloud amount is simply averaged. The remaining cloud properties are wieghted by their associated cloud amount. The log of the optical depth is used to average optical depths, since the log optical depth is approximately proportional to the visible radiance. The monthly mean is computed from the monthly hourly cloud properties. The separation of the daytime and nightime clouds are based on the solar zenith angle of 90°. If the monthly hourly SZA is less than 90°, the associated cloud properties are used to compute the daytime cloud properties.

The CldTypHist cloud properties are the same as found on the SYN1deg-hour/day/month Ed4 dataset. Whereas the SYN1deg cloud properties are stratified by 4 pressure layers (surface-700mb, 700mb-500mb, 500mb-300mb, and 300mb to 50mb), the CldTypHist cloud properties are stratified by 3x3 Pc-tau. The CldTypHist monthly mean 3x3 PC-tau cloud type properties have also been averaged as total cloud properties, as well as for day and night only monthly means. The ISCCP-D2like Ed3A cloud properties were organized into MODIS-day, MODIS-night, GEO-only, and merged products, in order to separate their inputs based on cloud retrieval quality. Night time clouds are not as reliable as daytime clouds, since they are based on IR channels only. GEO clouds are not as reliable as MODIS, since GEOs have fewer channels, broader spectral bands, and coarser pixel spatial resolution. The CldTypHist provides only one dataset, which combines the Terra and Aqua MODIS and the 1-hourly GEO clouds taking cloud quality into account. For hours with both a MODIS and a GEO observation, the MODIS measurement takes precedence (See Figure 1-4). Whereas, the ISCCP-D2like Ed3A product normalized the GEO clouds to MODIS, the CldTypHist Ed4A does *not* normalize the GEO clouds in order have consistent CldTypHist Ed4A and SYN1deg Ed4A clouds.

Figure 1-5 illustrates the combining of the Terra-MODIS (10:30 AM local equator crossing time (LECT)) and the 1-hourly GEO clouds during March 2000. For GEO M/5-ch domains all hour boxes contain observations. For the tropics, there are typically two Terra-MODIS measurements, one at 10:30 AM and one at 10:30 PM. The remaining hour boxes are from GEO M-ch retrievals. For the GEO nighttime 2-ch domains, no nighttime GEO hour boxes are filled and remain empty, but do contain the nighttime Terra and Aqua measurements. During the day the GEO 2-ch domain are all filled in a similar fashion to the GEO M/5-ch comains. Figure 1-5 displays how the Terra, GEO M/5-ch, and GEO 2-ch is cloud amount is combined regionally. The GEO domains are identified by the labels in the bottom panel that shows the # of GEO observations. The Met-7, Met-5 and GMS-5 GEO domains contain GEO 2-ch retrievals. For 0-1 GMT (Figure 1-5 left panels) The Terra cloud amounts are in the top panel. The GEO cloud amounts exist for the GMS-5 domain, since that domain is illuminated by the sun, as indicated by the 4th panel that shows the cosine of the solar zenith angle. However, the GEO cloud amounts are default at night for Met-7 and Met-5. The CldTypHist Ed4A combines the Terra (takes precedence) and GEO and at night only the Terra cloud amounts are available over the Met-7 and Met-5 GEO 2-ch domains. For the 12-13 GMT hour box, the Met-7 and Met-5 GEO domains are in daylight and GMS-5 domain is in darkness. Figure 1-6 demonstrates the combining of Terra (10:30 AM LECT), the Aqua (1:30 PM LECT) MODIS and the 1-hourly GEO clouds during June 2008. The two Aqua-MODIS measurements are at 1:30AM and 1:30 PM and only overlap with Terra at the poles. If there are both Terra and Aqua observations in the same hour box then the satellite with the lower view angle takes precedence. Only Met-7 conatins GEO 2-ch clouds. Besides night time GEO 2-ch domins, there are regions poleward of 60° N and 60° S where no clouds are available, since the regions are not observed by either Terra or Aqua and the GEO domain is limited to 60° in latitude. For example over Canada during June 2008 0-1 GMT (Figure 1-5).

1.2 Synergy between the CERES CldTypHist and FlxbyCldTyp Products

The CERES project will shortly release the CERES FluxByCldType Ed4 product, which provides CERES SW and LW TOA fluxes as a function of 3x3 PC-tau cloud types. The FluxByCldType product is an instantaneous gridded 1°-regional product that follows the orbit of either the Terra or Aqua satellites and contains no GEO cloud properties or fluxes. The CERES-FluxByCldType Ed4 product computes the CERES SSF sub-footprint fluxes by employing MODIS multi-channel radiance to broadband radiance empirical relationships based on single-layer and clear-sky footprints. The FluxByCldType Ed4 product allows modelers to compare their simulated fluxes as a function of cloud type along the Terra/Aqua ground tracks with the corresponding CERES fluxes. Along with the CERES FluxByCldType product, a CERES-MODIS simulator will provided so that the model output can be directly compared to the MODIS cloud retrievels and CERES fluxes. (Eitzen et al. 2017)

We urge users to visit the new CERES Data subsetting/visualization/ordering tool, which provides vastly improved user interface and a wider range of data formats (e.g., ASCII, netCDF) than is available with the ASDC ordering tool, which is limited to HDF.

http://ceres.larc.nasa.gov

Table 1-1. Displays the GEO imager channels used to determine the cloud mask (M) and cloud property retrieval (R). The cloud retrieval algorithm is identified along the top row and the GEO satellites associated with cloud retrieval algorithm is listed in the second row.

channel	**2-ch**	**5-ch-12**	**5-ch-13.3**	**M-ch**
GEOs	GMS-5, Met-5, Met-7	GOES 8-11	GOES 12-15	Met 8-10, Him-8
visible	M,R	M,R	M,R	M,R
0.86µm				M
1.6µm				M,R (snow)
3.9 µm		M,R	M,R	M,R
6.7 µm		M	M	M
8.6				M
11 µm	M,R	M,R	M,R	M,R
12 µm		M,R		M,R
13 µm			R	R

Table 1-2. The CldTypHist cloud property parameter availability as a function of MODIS, GEO 5-ch, GEO 2-ch day, and GEO 2-ch night retrievals. For GEO 2-ch day the cloud particle radius is assumed to be 10μm and 30μm for liquid and ice, respectively. +The GEO-2ch LWP and IWP is computed from the assumed particle size and optical depth. *No GEO 2-ch cloud retrievals are available at night, since the optical depth is not available.

Cloud property	**MODIS Day/Night**	**GEO (M-ch, 5-ch retrieval)**	**GEO-day (2-ch retrieval)**	**GEO-night * (2-ch retrieval)**
Cloud Fraction	X	X	X	
Cloud Effective Pressure	X	X	X	
Cloud Effective Temperature	X	X	X	
Cloud Effective Height	X	X	X	
Cloud Top Pressure	X	X	X	
Cloud Top Temperature	X	X	X	
Cloud Top Height	X	X	X	
Cloud Optical Depth	X	X	X	
Cloud Particle Radius	X	X	10/30 μm	
Liquid/Ice Water Path	X	X	+	
Cloud IR Emissivity	X	X	X	

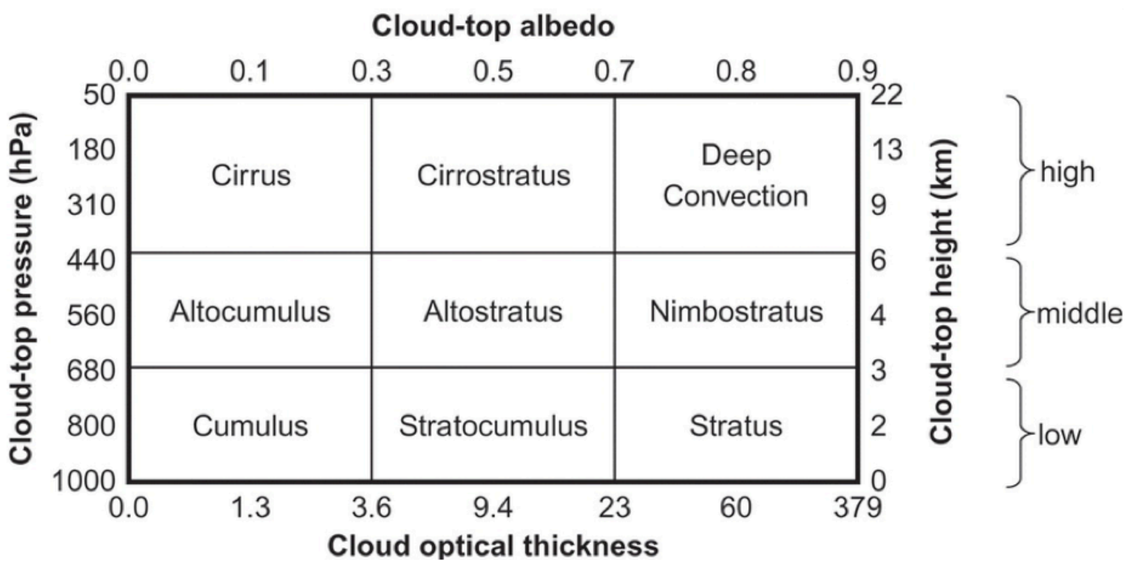


Figure 1-1. The 3x3 PC-tau histogram used in the CERES CldTypHist product. The cloud type names are given for the 9 cloud types, as well as the approximate cloud-top heights and cloud-top albedos.

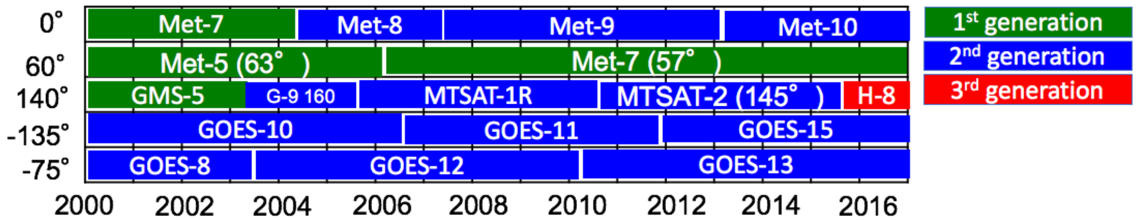


Figure 1-2. The GEO satellites used in the CERES CldTypHist product as a function of longitude position. G-9 and H-8 refer to GOES-9 and Himawari-8, respectively.

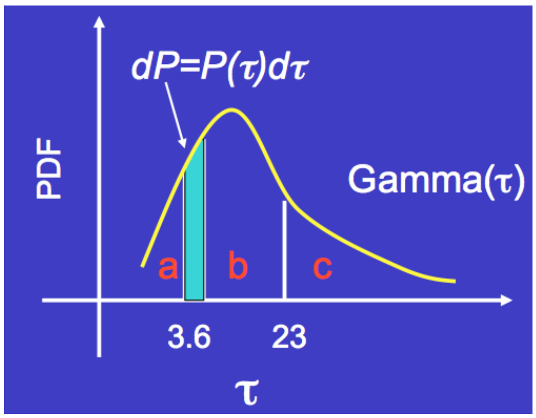


Figure 1-3. An illustration of the integration of the optical depth distribution for 3 optical depth bins (labeled a b c) based on the gamma distribution (yellow line) computed from the linear and log optical depth for a given GEO cloud layer.

For a region, at 0°E and 0°N, where local time=GMT

Local time: sunrise (GMT 6), noon (GMT 12), sunset (GMT 18), midnight (GMT 24)

Hour box	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
GEO M/5-ch	G	G	A	G	G	G	G	G	G	T	G	G	G	G	A	G	G	G	G	G	G	T	G	G
GEO 2-ch			A				G	G	G	T	G	G	G	G	A	G	G	G				T		

GMT 0 3 6 9 12 15 18 21 24

Figure 1-4. A hypothetical 1°-region located at 0° longitude and the equator, where the GMT and local time are identical, monthly GMT 1-hourly distribution of Terra-MODIS, Aqua-MODIS and GEO cloud retrieval inputs. The GEO 5-ch refers to the 2nd and 3rd generation GEO satellites, whereas the GEO 2-ch refers to the 1st generation GEO satellites shown in Figure 1-2.

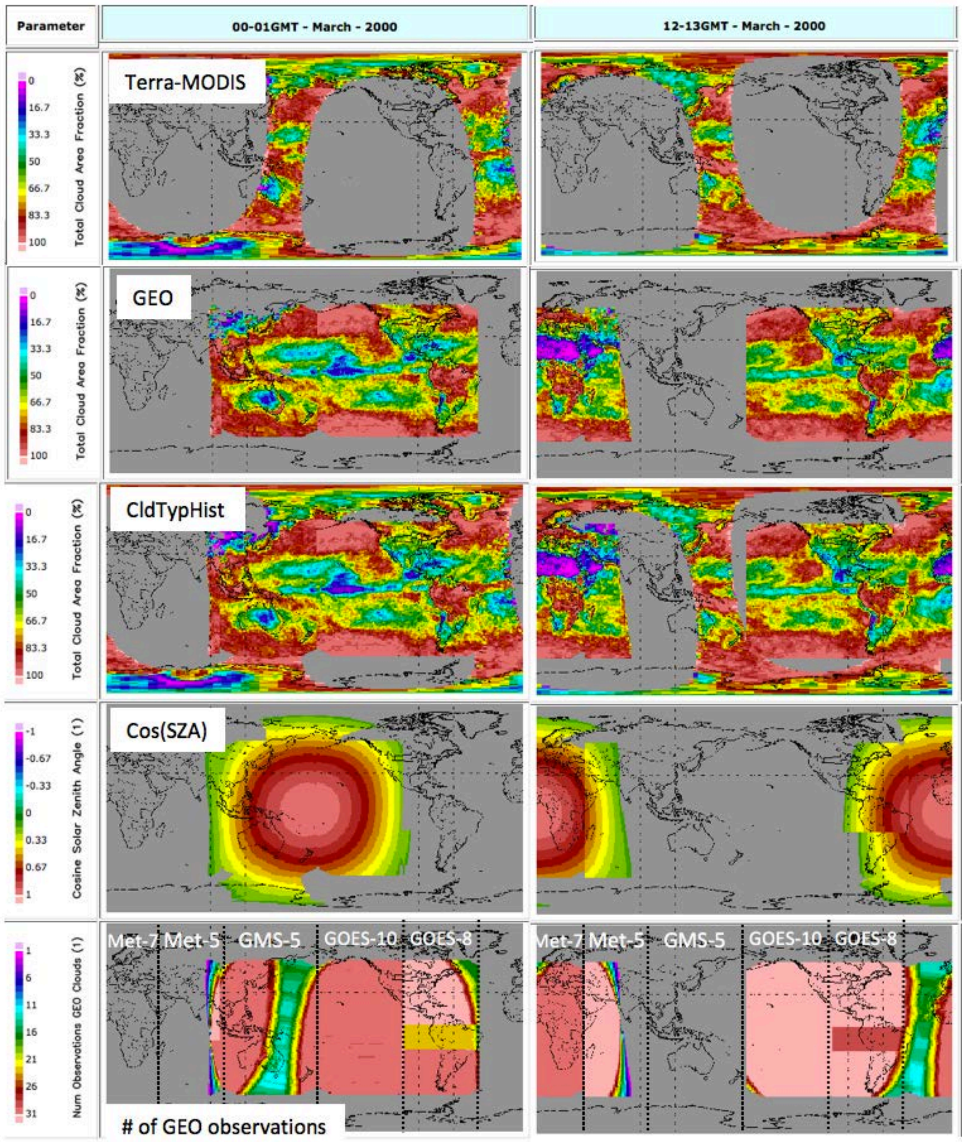


Figure 1-5. The March 2000 monthly 0-1 GMT hourly (left panel plots) and 12-13 GMT (right panel plots) mean cloud amount for Terra-MODIS, GEO-only, CldTypHist or Terra-MODIS and GEO combined, cos(SZA), and # of GEO observations (top to bottom). Met-7, Met-5, and GMS-5 are GEO-2ch satellites and do not provide night time cloud properties, whereas GOES-8 and GOES-10 are GEO 5-ch satellites and provide night time cloud properties for the CldTypHist product.

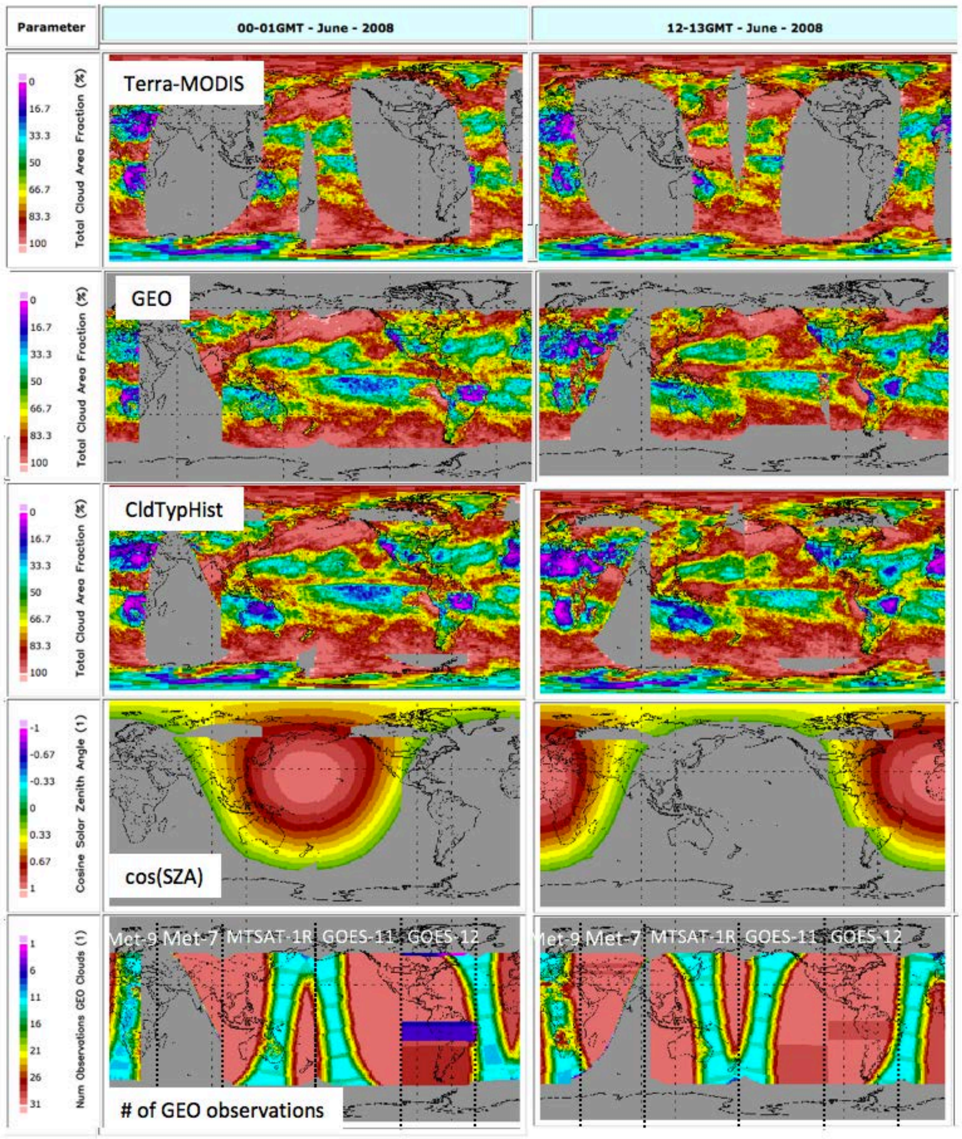


Figure 1-6. Same as Figure 1-5, except for June 2008. Met-7 is a GEO-2ch satellites and do not provide night time cloud properties, whereas the remaining satellites are GEO 5-ch and provide night time cloud properties for the product.

1.3 CERES Processing Level and Product Description

This section explains the CERES processing flow from level 0 to level 3 products; the steps are summarized in Table 1-3. This section also briefly describes all of the publicly available CERES products and their processing differences to help the user find the appropriate product for their application.

CERES instruments fly on the Terra (descending sun-synchronous orbit with an equator crossing time of 10:30 A.M. local time) and Aqua or NPP (ascending sun-synchronous orbit with an equator crossing time of 1:30 P.M. local time) satellites. Each CERES instrument measures filtered radiances in the shortwave (SW; wavelengths between 0.3 and 5 µm), total (TOT; wavelengths between 0.3 and 200 µm), and window (WN; wavelengths between 8 and 12 µm) regions. Unfiltered SW, longwave (LW) and WN radiances are determined following Loeb et al. (2001). CERES instruments provide global coverage daily, and monthly mean regional fluxes are based upon complete daily samples over the entire globe.

Raw digitized instrument data (Level 0) are converted to instantaneous filtered radiances (Level 1) using the latest CERES gains (Thomas et al., 2010). Time-dependent spectral response function values are then used to correct for the imperfect spectral response of the instrument and convert the filtered radiances into unfiltered SW, LW and WN radiances (Loeb et al. 2001; Loeb et al., 2016). Since there is no LW channel on CERES, LW daytime radiances are determined from the difference between the TOT and SW channel radiances. Instantaneous TOA radiative fluxes (Level 2) are estimated from unfiltered radiances using empirical ADMs (Su et al., 2015a) for different scene types identified using cloud property retrievals from MODIS measurements (Minnis et al. 2011). Their accuracy has been evaluated in several articles (Loeb et al. 2006; Loeb et al. 2007; Kato and Loeb 2005; Su et al., 2015b).

Monthly mean fluxes (Level 3) are determined by spatially averaging the instantaneous TOA flux values on a 1°×1° grid, temporally interpolating between observed values at 1-h increments for each hour of every month, and then averaging all hour boxes in a month (Doelling et al. 2013). CERES employs the CERES-only (CO; CERES SSF1deg stream) and the CERES-geostationary (CG; CERES SYN1deg stream) temporal interpolation methods. The CO method assumes that the cloud properties at the time of the CERES observation remain constant and only accounts for changes in albedo with solar zenith angle and diurnal land heating, by assuming a shape for unresolved changes in the diurnal cycle. The CG method enhances the CERES data by explicitly accounting for changes in clouds and radiation between CERES observation times using 1-hourly imager data from five geostationary (GEO) satellites that cover 60°S-60°N at any given time.

The Energy Balanced and Filled (EBAF, Level 3B) leverages off of the CERES Level 1-3 data products to produce a monthly TOA flux dataset that maintains the excellent radiometric stability of the CERES instruments while at the same time incorporating diurnal information from geostationary satellites in such a way as to minimize the impact of any geostationary imager artifacts that can occur over some geostationary domains and time periods. In order to ensure EBAF TOA fluxes satisfy known global mean energy budget constraints (e.g., based upon in-situ data from the Argo network, Roemmich et al. 2009), SW and LW TOA fluxes are adjusted within their range of uncertainty using an objective constrainment method (Loeb et al., 2009). Importantly, this is a one-time adjustment applied to the entire record. Therefore, the time-dependence of EBAF TOA fluxes is tied as closely as possible to the CERES instrument radiometric stability. Unlike other CERES data products, EBAF provides monthly regional clear-sky TOA fluxes that are free of missing regions by making optimal use of coincident CERES and MODIS measurements.

Table 1-3. Processing descriptions for CERES Level 1-3 data products.

Level	Description	Data Product
0	Raw digitized instrument data for all engineering and science data streams in Consultative Committee for Space Data Systems (CCSDS) packet format.	
1B	Instantaneous filtered broadband radiances at the CERES footprint resolution, geolocation and viewing geometry, solar geometry, satellite position and velocity, and all raw engineering and instrument status data.	BiDirectional Scans (BDS)
2	Instantaneous geophysical variables at the CERES footprint resolution. Includes some Level 1B parameters and retrieved or computed geophysical variables (e.g., filtered and unfiltered radiances, viewing geometry, radiative fluxes, imager radiances, cloud and aerosol properties).	SSF
3	Radiative fluxes and cloud properties spatially averaged onto a uniform grid. Includes either instantaneous averages sorted by GMT hour or temporally interpolated averages at 1–hourly, daily, monthly or monthly hourly intervals.	SSF1deg–Hour, SSF1deg–Day, -Month, SYN1deg-Hour, -Day, -MHour, -Month

2.0 Cautions and Helpful Hints

The CERES Science Team notes several CAUTIONS regarding the use of CERES_D2like_Ed3A:

General

- The CERES_SSF1deg Hour/Day/Month_Ed4.0 products can be visualized, subsetted, and ordered from: http://ceres.larc.nasa.gov.

- A full list of parameters in the CERES CldTypHist is contained in the Data Product Catalog (PDF) (provide link).

- Users should be aware that some of the key inputs used to produce the SSF1deg changed at various times during the data record. Such changes, if large enough, may introduce spurious, unphysical jumps in the record. In the past, these changes were reflected in each CERES data product's version through a letter change (e.g., SRBAVG Edition2A, Edition2B, etc.). However, this proved cumbersome and confusing to many users. Therefore, for the SSF1deg product, letter changes will only reflect a reprocessing of the data record (e.g., due to a code bug). Major algorithm improvements will be noted as Editions. Changes to inputs are documented at the following web site (https://ceres.larc.nasa.gov/science_information.php?page=input-data). The web site provides a time-line of all input data source changes to date used to produce the CldTypHist Ed4A products. Users are advised to use this table as a reference in their analysis of CldTypHist products. This especially applies when GEO satellites are replaced.

- Processing is performed on a nested grid. This grid uses 1° equal-angle regions between 45°N and 45°S and maintains area consistency at higher latitudes. The product contains a complete 360x180 1° grid created by replication.

Table 2-1. CERES nested grid.

Latitude segment	# of zones in segment	Longitude extent (°)	# of regions/zone	# of regions in segment
Equator to 45°	90	1°	360	32400
45° to 70°	50	2°	180	9000
70° to 80°	20	4°	90	1800
80° to 89°	18	8°	45	810
89° to 90°	2	360°	1	2
Total	180	-	-	44012

Clouds

- No zonal or global averages are provided with the CldTypHist Ed4A product

- The cloud properties are provided as monthly 1-hourly, monthly, monthly-day, and monthly-night. The 3x3 PC-tau cloud types have also been averaged into total cloud properties, which should be similar to the clouds in the SYN1deg product.

- When averaging cloud properties, wieght by the associated cloud fraction. When averaging optical depths, use log optical depths. Averaging of liquid and ice water paths and particle sizes should be avoided.

- **The day and night time CldTypHist GEO or MODIS cloud property differences may be a result of the retrieval algorithm**. **The MODIS and GEO cloud properties will also differ.** The MODIS and GEO daytime cloud properties are retrieved from both visible and IR MODIS bands, whereas as night only the IR bands are used. It is very difficult to obtain accurate optical depths for thick clouds using only IR channels. The cloud parameter differences between day and night as shown in Table 2-2. The nighttime LWP, IWP are underestimated, when compard with the more reliable daytime retrievals. Night time cloud fraction, height and IR emissivity are greater, higher and less than their daytime counterparts, respectively. It is also possible that some of the GEO and MODIS cloud differences are caused by diurnal cloud property variations. The MODIS cloud properties are only sampled during Terra (10:30 AM LECT) and Aqua (1:30 PM LECT) overpass times.

- **The CldTypHist GEO properties will more than likely show cloud parameter value discontinuities in between GEO domains**. Figure 2-1 clearly shows LWP and IWP discontinuties between GEO domains for both day and night. Also the GEO day and night cloud properties will differ. Cloud fraction is the most consistent of all cloud properties between day and night and across GEO boundaries both in time and space. Cloud top/effective/base pressure/hieght/temperature are slightly more impacted. Particle size, IWP/LWP, IR emissivity and optical depth are greatly dependent on GEO satellite and day/night conditions (See Section 4.2).

- Table 2-3 documents the GEO sequence of satellite for each GEO domain as a function of date. Also the GEO domain boundaries are listed. An error was found in the GEO boundary code for CldTypHist data generated between 2008 and 2010. This issue was corrected for the remaing time period. This impacted the 0° and 60° boundary, which was shifted to 28° between 2008 and 2010, where the rest of the time period used 41° as the boundary. **Analyzing clouds across GEO boundaries both in space and time should be avoided if possible**.

- For Met-10, MTSAT-2 and GOES-13, datagaps occurred and the backup GEO satellite was used to fill in the datagap cloud properties (See Table 2-4). The datagaps are listed on the the CERES data inputs web, which is updated in near realtime (pagehttps://ceres.larc.nasa.gov/science_information.php?page=input-data#). These GEO switchings will also potentially show cloud parameter value discontinuities. GOES-13 suffered outages, when the backup satellite GOES-14 located at 90° was slowly moved into the GOES-13 position. After the GOES-13 outage the GOES-13 was moved back into the GOES-13 position. MTSAT-1R was used as a backup satellite during the MTSTAT-2 ground station maintenance period. Met-8 and Met-9 were used as backups, when Met-10 was undergoing de-icing of its IR channels.

- Table 2-5 **provides a chart that recommends particular GEOs from a seqence of satellite within a GEO domain.** If the luxury of chosing a time period during the CERES record is available, then the table can be used to select the time period with the most robust and stable clouds. The GEO cloud quality is a function of the retrieval code, where the quality is a function of the number of channels. Another recommendation factor is the image quality. GOES-9 had a very noisy visible channel and has the lowest recommendation status in the whole CERES record. The GEO 2-ch have a recommendation a step above GEOS-9. Since the MTSAT-1R blurred visible optical path was mostly corrected, it has the same recommendation as the 2-ch GEOs. The GOES imagers have a higher recommendation with a slight preference given to the 12µm retrieval. The Meteosat 8-10 have an even higher recommendation. It must be pointed out that the cloud retrieval algorithm changed for Met-10, when an enhanced IR optical depth was implemented to increase the optical depths at night. The Himwari-8 and GOES-R are replicas of each other and have the highest recommendation, since they have a near MODIS retrieval algorithm.

- The CldTypHist product also provides the number of the GEO and MODIS observations used to obtain the monthly hourly means. **The number of observations can be used as a quality control indicator.** For each monthly hourly cloud value, the number of MODIS and GEO observations should equal to the number of days in the month. Measurements with a greater frequency of MODIS data should have a higher quality clouds than those based solely on GEO. Also over GEO 2-ch domains most night time hours will not have any GEO observations, since GEO 2-ch cloud retrievals do not have an accompanying optical depth, except for hours that either Terra or Aqua sample.

Table 2-2. The Terra and Aqua-MODIS 14-year mean cloud properties from July 2002 to June 2016 for nonpolar (±60° latitude) regions. These cloud properties were not obtained from the publicly available CldTypHist product, but were based on MODIS-only and GEO-only intermediate processing data.

Cloud property	**Day MODIS**	**Night MODIS**	**Day GEO**	**Night GEO**
Cloud Fraction (%)	65.9	69.2	67.4	69.3
Cloud Effective Pressure (mb)	610	536	647	584
Cloud Effective Temperature (K)	263	254	267	262
Cloud Effective Height (km)	4.9	6.2	4.3	5.2
Cloud Top Pressure (mb)	597	517	627	560
Cloud Top Temperature (K)	261	251	264	258
Cloud Top Height (km)	5.2	6.6	4.8	5.7
Liquid Particle Radius (μm)	13.8	11.0	15.6	10.3
Ice Particle Radius (μm)	25.2	27.7	30.0	22.8
LWP (gm^{-2})	83	51	111	45
IWP (gm-2)	201	52	295	83
IR Emissivity	0.80	0.70	0.83	0.77

Table 2-3. Dates when GEO satellites were replaced and the grid domain boundaries as a fuuntion of satellite equator longitude (listed across the top row). The GEO domain boundaries have no column headers and are placed between satellite position columns and contain the GEO boundary longitude as a function of the date along the left column.

Date	**0°**		**~60°**		**140°**		**-135°**		**-75°**	
March 1, 2000	Met-7	**42°**	Met-5	**98°**	GMS-5	**-178°**	GOES-10	**-105°**	GOES-8	**-38°**
April 1, 2003									GOES-12	
April 23, 2003				**110°**	G-9 (160°)	**-190°**				
April 2, 2004	Met-8									
July 6, 2005				**98°**	MTSAT-1R	**182°**				
June 22, 2006							GOES-11			
Jan 26, 2007		**41°**	Met-7							
April 12, 2007	Met-9									
January 1, 2008		**28°**								
April 15, 2010									GOES-13	
July 1, 2010					MTSAT-2					
January 1, 2011		**41°**								
December 6, 2011							GOES-15			
January 21, 2013	Met-10									
July 6, 2015					Himawari-8					
February 1, 2017			Met-8							

Table 2-4. Dates of the primary imager data gaps and backup satellite used to bridge the gap

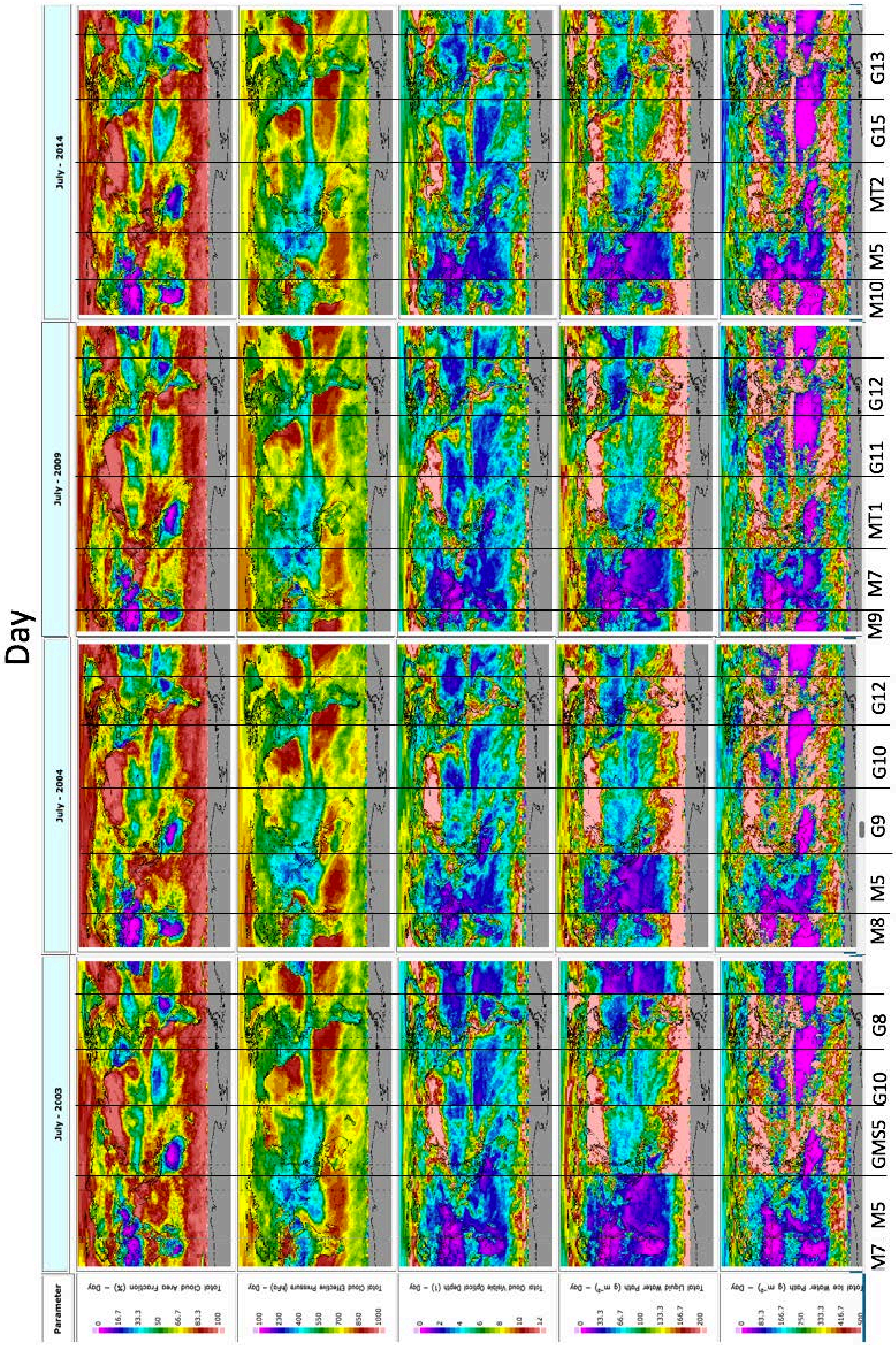
Primary Satellite	position	Operational record	Backup Satellite	Outage
Met-10	0°	Jan 21, 2013 to current	Met-8	July 2-8, 2013
			Met-9	Jan 15-20, 2014
			Met-8	Dec. 3-7. 2014
			Met-8	Nov 16-17, 2015
			Met-8	Dec 9-13, 2015
MTSAT-2	145°	July 1, 2010 to July 6, 2015	MTSAT-1R	Oct 17-Dec 22, 2010
			MTSAT-1R	Aug 3-16, 2011
			MTSAT-1R	Oct 31-Dec 25, 2011
			MTSAT-1R	Oct 18-Dec 26, 2012
			MTSAT-1R	Oct 23-Dec 18, 2013
GOES-13	-75°	April 15, 2010 to current	GOES-14	Sept 24-Oct17, 2012
			GOES-14	May 23-June 9, 2013

Table 2-5. CERES recommended GEO imager as a function of equator longitude position. A recommendation flag of green is the preferred satellite of the GEO domain.

Position	Satellite	Rec Flag	Cloud Flag	Operational Date	NOTES
0°	Met-7			March 1, 2000	
	Met-8			April 2, 2004	Cloud code Met-8 and Met-9 are consistent
	Met-9			April 12, 2007	Cloud code Met-8 and Met-9 are consistent
	Met-10			Jan 21, 2013	Met-10 cloud code revised from Met-9, which enhanced optical depths
~60°	Met-5			March 1, 2000	
	Met-7			Jan 26, 2007	
	Met-8			Feb 1, 2017	
140°	GMS-5			March 1, 2000	
	GOES-9			April 23, 2003	Very noisy visible images
	MTSAT-1R			July 6, 2005	Visible imager optical blurring not completely removed
	MTSAT-2			July 1, 2010	
	Himawari-8				Similar to GOES-R
-135°	GOES-10			March 1, 2000	
	GOES-11			June 22, 2006	
	GOES-15			Dec 6, 2011	
-75°	GOES-8			March 1, 2000	
	GOES-12			April 1, 2003	
	GOES-13			April 15, 2010	

Recommend Flag	Least Reliable			Preferred

Cloud Code	2-ch	5-ch-12	5-ch-13.3	Multi-ch


Day
Parameter
July - 2003
July - 2004
July - 2009
July - 2014
M7
M5
GMS5
G10
G8
M8
M5
G9
G10
G12
M9
M7
MT1
G11
G12
M10
M5
MT2
G15
G13

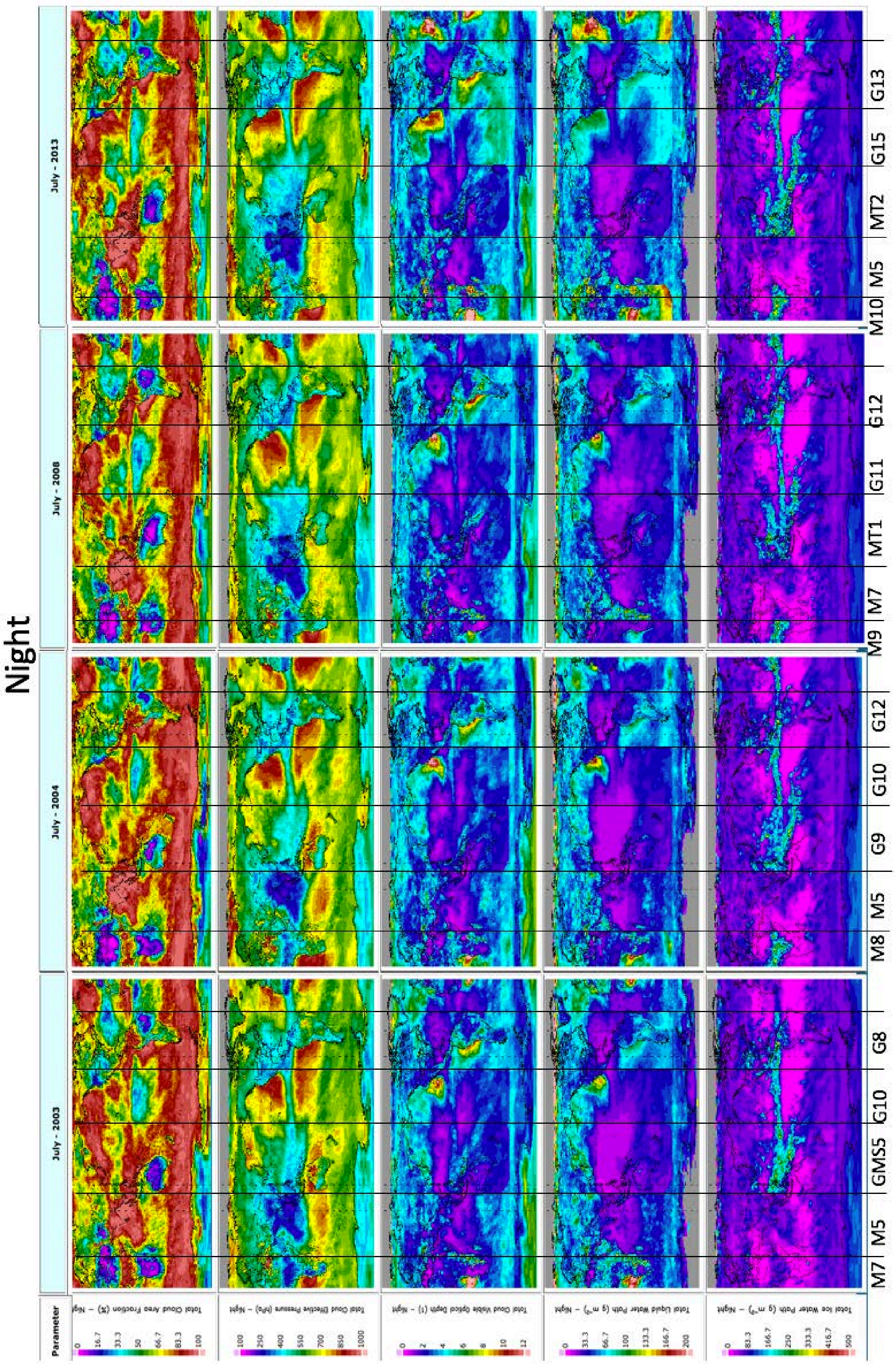

Night
Parameter
July - 2003
July - 2004
July - 2008
July - 2013
M7 M5 GMS5 G10 G8
M8 M5 G9 G10 G12
M9 M7 MT1 G11 G12
M10 M5 MT2 G15 G13

Figure 2-1. The CERES CldTypHist Ed4A product day-time (top page) and night-time (bottom page) cloud fraction (%) (range: 0 to 100), cloud effective pressure (mb) (range: 1000 to 100), cloud optical depth (range:0 to 12), LWP(gm^{-2}) (range: 0 to 200) and IWP (gm^{-2}) (range: 0 to 500) during July 2003, July 2004, July 2008 and July 2014. The horizontal thin black lines denote the GEO boundaries. M5->Meteosat-5, M7->Meteosat-7, M8->Meteosat-9, M10->Meteosat-10, G8-< GOES-8, G9->GOES-9, G10->GOES-10, G11->GOES-11, G12->GOES-12, G13->GOES-13, G15->GOES-15, MT1-< MTSAT-1R, MT2->MTSAT-2

3.0 Version History

This section discusses the Edition 4 algorithm and input improvements. Both the MODIS and GEO cloud retrieval algorithms were significantly improved in Edition 4A and are sumarized in Section 3.1. The MODIS collection and GEOS atmospheric profile versions are listed for both Edition 3 and 4 and highlights the improvements when processing with consistent versioning.

3.1 Changes between ISCCP-D2like Ed3A and CldTypHist Ed4A algorithms

This section discusses the Edition 4 algorithm and input improvements. Section 3.1.1 describes the MODIS cloud property retrieval improvements in Edition 4 compared with Edition 3. Section 3.1.2 describes the GEO sampling frequency, image quality control strategy, the GEO calibration procedure, the retrieval spatial resolution, cloud property retrieval algorithms, and CldTypHist product differences between Editions 3 and 4.

3.1.1 MODIS Ed4A algorithm improvements

Improvements to the CERES MODIS cloud algorithm in Ed4 compared to Ed3A include using regional mean boundary apparent lapse rates developed using collocated CALIPSO and MODIS data to determine low cloud-top height (Sun-Mack et al., 2014), a CO_2-slicing method to retrieve high cloud over low-lying clouds (Chang et al., 2010), a rough ice crystal model (Yang et al., 2008) to improve ice cloud retrieval. A detailed description of the Edition 4 cloud algorithm is in preparation. Also the Terra and Aqua MODIS cloud retrievals were made more consistent, especially over polar regions.

The Ed4A MODIS cloud mask substantially improves detection of thin cirrus and low cloud, provides a better discrimination between cloud and dust, and substantially improves cloud detection in polar regions. The cloud mask improvements include the use of additional MODIS channels and threshold tests (MODIS 1.38 µm threshold test, T3.7-T11 and T11-T12 difference tests, 2.1 to 0.6 µm ratio test, 1.24 to 0.65 µm ratio test, and new visible threshold tests) derived with the benefit of years of CALIPSO data for guidance. In contrast, the EBAF Ed2.8 cloud mask was developed prior to CALIPSO. The Ed4.0 cloud mask substantially improves detection of thin cirrus and low cloud, provides a better discrimination between cloud and dust, and substantially improves cloud detection in polar regions.

Because the Aqua MODIS 1.6 µm channel failed shortly after launch, the 1.24 µm channel is used as an alternative in both Aqua and Terra Ed4 daytime cloud optical depth retrievals over snow. However, the 1.24 µm channel is not optimal for cloud optical depth since surface reflectance can affect retrievals more than the 1.6 µm channel. Surface shortwave downward flux validation of radiative transfer results over Dome C using 1.6 µm and 1.24 µm cloud retrievals anecdotally suggest that the 1.24 µm cloud optical depths for thin clouds over snow can be as large as a factor of two.

The 1.24 µm and 2.1µm based liquid and ice particle size, and optical depth are not provided in the CldTypHist Ed4A or in the SYN1deg Ed4A and can only be accessed in the SSF1deg Ed4A product.

The MODIS Collection 5 was used from March 2000 to March 2017 to retrieve the Aqua and MODIS cloud properties available in the CldTypHist Ed4A product. Beginning in April 2017 only Collection 6 (C6) MODIS data will be available and Collection 5 (C5) will no longer be available. In order to minimize any cloud property value differences between the two collections the MODIS C6 channel radiances will be scaled to C5 to provide MODIS equivalent C5 radiances from the C6 pixel radiance dataset. This is accomplished by taking an identical C5 and C6 MODIS granule and regressing the pixel-level C5 and C6 radiance pairs. The slope through the origin is used to adjust the C6 visible channel calibration. A 2nd order radiance fit is used to adjust the IR radiance. The 2nd order fit provides the non-linear adjustment needed for the cold end, especially for band 20 (3.8µm) at night and the water vapor band 27 (6.7µm). The C6 calibration is considered more accurate than C5, since it takes into account the visible channel scan angle dependencies. It must be noted that the CERES cloud working group did adjust the Terra-MODIS band 20 C5 temperature to better match Aqua-MODIS for the cold end (SSF Ed4 DQS). This was left in place, and the C6 to C5 scaling did not remove the original C5 adjustment.

3.1.2 GEO Ed4A algorithm improvements

Substantial cloud retrieval algorithm changes were made between GEO Ed3A and Ed4 products and are summarized in Table 3-1. Both Editions use visible 1-km and IR 4-km pixel resolution images, which are sub-sampled to 8-km. The Ed3A only ingested the GEO visible and IR window channels, whereas for Ed4A all channels were downloaded (See Table 1-1). For Ed3A 3-hourly GEO full disc (FD) imagery is incorporated, synchronized at 0, 3, 6 UTC, etc., following the ISCCP project GEO sampling. For Ed4A the same 3-hourly FD imagery is incorporated and 1-hourly additional GEO imagery is integrated to provide 1-hourly GEO sampling. The GEO imagery is inserted into the proper hour box defined by 0-1, 1-2, … GMT. See Table 3-2 for the exact GEO image times assigned to the hour box. Unfortanately, the scan times are not synchronized across GEO domains. Greater GEO scan synchronoziation is planned for Ed5A. The MTSAT-1R visible optical was slightly blurred causing a non-linear radiance response (Doelling et al. 2015). The Ed3A cloud retrievals were based on the uncorrected MTSAT-1R visible imagery, whereas the Ed4A applied a pixel-level point spread function (PSF) to correct most of the optical blurring (Khlopenkov et al. 2015). The MTSAT-1R GEO cloud retrievals were improved using the PSF correction in Ed4A.
The GEO image quality is compromised by bad scan lines, navigation (image rectification) errors, straylight conditions during equinox conditions (Met-5, Met-7 WV channel), electronic interference patterns (GOES-9 visible channel), and vertical striping swaths (MTSAT-1R all channels). The GEO image quality is dependent on the individual GEO, but in general, is worse at the beginning of the CERES record (2000) and improves over time. The 1st generation GEO images have more image artifacts than the 3rd generation. For Edition 3A GEO imager artifacts were not removed before January 2012, afterwhich, the GEO imagery was visually examined. Easily identified articacts were removed from the 3-hourly imagery. Visual examination is a labour intensive process and

to visually inspect 1-hourly multiple channel imagery is unfeasible. An automated bad scan line detection program was implemented for Ed4A over the whole record (Khlopenkov and Doelling 2016). The automated program identified GEO images with artifacts which were then visually inspected to make sure only the actual bad scan lines are removed, since the automated program tended to have a few false positives in order to ensure that all artifacts were detected. Straylight artifacts tend to occur during equinox at specific GMT times and can only be detected by visual examination and removed during these time intervals. After the GEO image channel radiances and temperatures and their respective cloud properties are gridded into 1° regions and composited into hourly global maps. Hourly "movies" of the regional gridded hourly channel radiances and temperatures are inspected for any 1° regional artificial temporal features that appear for short durations, such as navigation shifts and temperature drifts, and straylight features (slides 17-28 https://ceres.larc.nasa.gov/documents/STM/2015-05/9_CERES_TISA_Doelling_2015_05.pdf).

The GEO imager calibration was improved between Ed3A and E4A. The primary GEO visible imager calibration is based on the GEO and Terra-MODIS Collection 5 (C5) band 1 (0.65µm) ray-matched radiance pairs (Doelling et al. 2013). The Terra-MODIS C5 band 1 was not stable over time. There were two calibration anomalies in late 2003 and early 2009, where the calibration degraded by 1% and 1.5%, respectively (Wu et al. 2013). The Terra-MODIS cloud optical depth retrievals also manifested these anomalies (See Section 4.0). The Ed4A GEO visible imager calibration uses Aqua-MODIS C6 band 1 as the calibration reference. The Aqua-MODIS was stable until 2008 and then started to slowly degrade by 1% over the rest of the record (Doelling et al. 2015 Terra-Aqua scaling). This degradation has a scan angle dependency, where one side of the scan degraded more than the other side (Bhatt et al. 2017). These issues should be resolved in MODIS C6.1.

The Ed3A GEO/MODIS ray-matched radiance 50-km pairs over tropical all-sky ocean was improved by using strict a 5° vew and azimuthal angle matching for near clear conditions and relaxing the angles to within 15° for bright cloud conditions (a.k.a. graduated angle matching) for Ed4A (Doelling et al. 2016). The GEO and MODIS spectral band differences were not accounted for in Ed3A. For Ed4A the spectral band adjustment factors (SBAF) were based on pseudo GEO and MODIS SCIAMACHY hyper-spectral radiances, which were convolved with their respective GEO and MODIS spectral response functions. The SCIAMACHY footprint GEO and MODIS pseudo MODIS radiances were regressed with a second order fit to estimate the SBAF and then applied to the MODIS radiances to make them spectrally equivalent to the GEO radiances.

The primary GEO calibration gains were also compared to the GEO/MODIS ray-matched radiance 30-km pairs obtained over deep convective cloud (DCC) cores. DCC have the smallest Earth viewed SBAF (Doelling et al. 2016). The primary calibration is also validated using both invariant desert (Bhatt et al. 2014) and DCC targets (Doelling et al. 2011). These invariant targets have been characterized using a reference GEO over each

GEO domain, which has been calibrated with the primary method. Generally, all of the validation GEO visible calibration gains were within 1% of the primary gain.
A multiple channel GEO cloud retrieval code that is similar to MODIS, limited by GEO available channels (See Table 1-1), was implemented for Ed4A, for all 2nd and 3rd generation GEO satellties (See Figure 1-2). The GEO cloud code was optimized for each set of GEO imager channels. The pixel-level retrieved cloud properties are assigned to the appropriate PC-tau bin according to their cloud effective pressure and cloud optical depth (See Figure 1-1) and by liquid or ice phase. A pixel is classified as either clear or cloudy. The pixel-level cloud properties are then gridded into PC-tau bins. Optical depth is averaged in log form, which is proportional to radiance.

The 1st generation GEO imagers continued to use the Ed3A visible and IR channel cloud retrieval code (See Figure 1-2). For the GEO 2-ch imagers the visible and IR channels were calibrated to have equivalent MODIS radiances in order to facilitate a single GEO cloud algorithm to process all GEO satellites. The GEO 2-ch cloud retrieval code does not output pixel-level clouds, but rather 1° regional cloud layers. To estimate the optical depth for each optical depth bin a gamma distribution based on the log and linear averaged optical depth is used. (See Figure 1-3). The integration over the optical depth bin range designates the optical depth. To compute the liquid water path (LWP) and IWP a particle size of 10 µm and 30µm in radii are assumed. At night, the 1st generation GEO cloud properties, are not incorporated in the CldTypHist product, since they are based on a single IR channel and do not have associated optical depths. The CldTypHist Ed4A product does not normalize the GEO clouds with MODIS as was implemented in the ISCCP-D2like Ed3A product. Normalizing at Terra and Aqua overpass times may not be applicable to sunrise and sunset conditions and may not provide accurate diurnal cloud information.

The CldTypHist Ed4A product is obtained from hourly instantaneous MODIS and GEO clouds, where the MODIS observations take precedence over the GEO measurements. The CldTypHist Ed4A product monthly hourly and monthly cloud properties are then computed from the hourly clouds to provide the best estimate of the regional diurnally cloud properties. The CldTypHist Ed4A MODIS and GEO cloud properties may differ from the diurnally incomplete but superior MODIS-only clouds. Whereas the ISCCP-D2like Ed3A also provided MODIS-day, MODIS-night, GEO-day, and Merge (MODIS day/night and GEO day), the CldTypHist Ed4A product only provides the merged product (MODIS day/night, GEO M-ch day/night and GEO 2-ch day). The CldTypHist Ed4A does not provide 7x6 PC-tau cloud fraction bins, that were available in the ISCCP-D2like product for the MODIS-only products. The CldTypHist Ed4A product provides the number of GEO and MODIS measurements used to compute the monthly mean cloud properties, which can be used as a quality control indicator and to identifiy whether MODIS or GEO cloud retreivals were used.

The CldTypHist Ed4A was designed to faithfully represent as much as possible the SYN1deg Ed4A product clouds. The SYN1deg Ed4A did temporally interpolate within the layered cloud bins, when there were data gaps in the GEO record and at night over the GEO 2-ch domains. Over the night time GEO 2-ch domains, the observed emissivity was assumed to be unity in the SYN1deg Ed4A product. The CldTypHist Ed4A and SYN1deg Ed4A monthly cloud properties are usually consistent over the GEO M/5-ch domains, since very few data gaps exist in the hourly cloud observations that required temporal interpolation.

Table 3-1. Summary of the GEO cloud retrieval algorithm differences between the ISCCP-D2like Ed3A and the CldTypHist Ed4 product

Product	**ISCCP-D2like Ed3A**	**CldTypHist Ed4A / SYN1deg Ed4A**
GEO image sampling	• 3-hourly	• 1-hourly • MTSAT-1R point spread function • bad scan line removal
GEO spurious scan and artifact removal	• Visually inspected visible and IR images • Initiated in January 2012	• Automated bad scan line removal • Visually inspected for artifacts (stray-light) • Applied over the entire record
GEO calibration reference	• Terra-MODIS Band 1 (0.65µm) Collection 5	• Aqua-MODIS Band 1 (0.65µm) Collection 6
GEO calibration method	• GEO/MODIS all-sky tropical ocean ray-matching	• GEO/MODIS all-sky tropical ocean ray-matching
GEO calibration validation	• Primary: GEO/Terra-MODIS Collection 5 Band 1 (0.65µm) ray-matching	• Primary: GEO/Aqua-MODIS Collection 6 Band 1 (0.65µm) ray-matching • GEO/MODIS deep convective cloud (DCC) ray-matching • Invariant desert and DCC calibration • SCIAMACHY based spectral band adjustment factors (SBAF)
GEO retrieval resolution	• 1° gridded with 4 PC layers	• pixel level
GEO tau distribution	• gamma distribution	• pixel distribution
GEO particle size retrieval	• Assume 10µm and 30µm liquid and ice	• Retrieved based on 3.9µm
GEO night emissivity	• Assume night emissivity = 1	• Emissivity based on IR channels
GEO/MODIS cloud property normalization	• normalization applied in the Merge product	• No normalization applied
Cloud types	• 9 cloud types: all parameters provided • 42 cloud types: MODIS cloud fractions only	• 9 cloud types: all parameters provided • 42 cloud types: not provided
Products	• 4 products MODIS-day, MODIS-night, GEO-day, Merge (MODIS day/night, GEO-day)	• 1 product (MODIS and GEO day/night)

Table 3-2. The GEO image start time used to fill in the CldTypHist hour box cloud properties. Also listed are the complete GEO scan schedules.

Cloud property	Equator longitude	3-hourly FD	Remaining hours	Scan Schedule
Met-5, Met-7	62°, 57°	0:30, 3:30	1:30, 2:30	30' FD
Met-8	42°	0:00, 3:00,	1:00, 2:00	15' FD
Met-7	0°	0:30, 3:30	1:30, 2:30	30' FD
Met-8, Met-9, Met-10	0°	0:00, 3:00,	1:00, 2:00	15' FD
GOES-East	75° W	2:45, 5:45, …	0:45, 1:45, .. NH 0:09, 1:09, … SH	3-hourly FD 30' NH and SH
GOES-West	135° W	0:00. 3:00, …	1:00, 2:00, .. NH 1:22, 2:22, … SH	3-hourly FD 30' NH and SH
GMS-5	140°	2:30, 5:30, …	1:30, 2:30	30' or 60' FD or NHE
GOES-9	160°	2:30, 5:30, …	1:30, 2:30	30' or 60' FD or NHE
MTSAT-1R	140°	2:30, 5:30, …	1:30, 2:30	30' or 60' FD or NH
MTSAT-2	145°	2:30, 5:30, …	1:30, 2:30	60' FD
Himawari-8	140°			10' FD

3.2 Input Changes Between ISCCP-D2like Ed3A and CldTypHist Ed4A

This section highlights the major input changes between the ISCCP-2like Ed3A and CldTypHist Ed4A products. The CERES project strives to process the entire data record using consistent version input sources as well as processing the CERES editions with the same algorithms. Any change in the input version or processing algorithm may introduce artifacts in the record and should not be interpreted as natural variability. This requirement is sometimes difficult to achieve, since input versions may be discontinued.

A complete list of input version changes are listed on the following website: https://ceres.larc.nasa.gov/science_information.php?page=input-data. The two most significant input changes are in the versions of the MODIS and GEOS products (Table 3-1).

Table 3-3. The MODIS and GEOS versions used in SSF1deg Ed3A and Ed4A.

	Ed3A	Ed4A
MODIS	Collection 4 from Mar 2000 Collection 5 from Apr 2006	Collection 5 from Mar 2000 Collection 6 from Jan 2017
GEOS	GEOS-4 from Mar 2000 GEOS-5.2 from Jan 2008 GEOS-5.4.1 from March 2016	GEOS-5.4.1 from Mar 2000

In Section 3.2.1 the Terra optical depth and and Section 3.2.2 the GEOS Ed3A input trend anomalies are discussed along with their Ed4A improvements. Comparison plots show the impacts.

3.2.1 Terra Cloud Optical Depth

The CldTypHist product uses the Terra-MODIS optical depths during 10:30 local time. The improvement is shown with the SSF1deg EF4Aproduct. The CldTypHist uses the same Terra-MODIS optical depths. The Ed4A input improvement comparison is made with SSF1deg Ed4A-Terra for simplcity.

The Terra-MODIS instrument band 1 (0.65-µm) experienced two calibration anomalies over the CERES record. Both MODIS instruments rely on lunar looks and the solar diffuser for on-orbit stability. The first anomaly occurred on July 2, 2003 when the solar diffuser door on the Terra-MODIS malfunctioned and was left in the open position. This darkened the Terra-MODIS optics by 1% (Minnis et al. 2008) and was unaccounted for in the Collection 5 dataset. The second anomaly occurred in early 2009, when the solar diffuser degradations were observed to be 1.5% and 0.3% for Terra-MODIS and Aqua-MODIS, respectively (Wu et al. 2013). The CERES cloud retrieval code mitigated both calibration anomalies by making adjustments to the Terra-MODIS radiances. (See https://eosweb.larc.nasa.gov/sites/default/files/project/ceres/quality_summaries/ssf_cloud_prop_terra-aqua_Ed4A.pdf.) These two Terra-MODIS calibration anomalies are easily identified in the Ed3A optical depth record during 2003 and 2009 in Figure 3-1**Error! Reference source not found.**. By explicitly accounting for these calibration anomalies in Ed4A, the cloud optical depths are now consistent over the record.

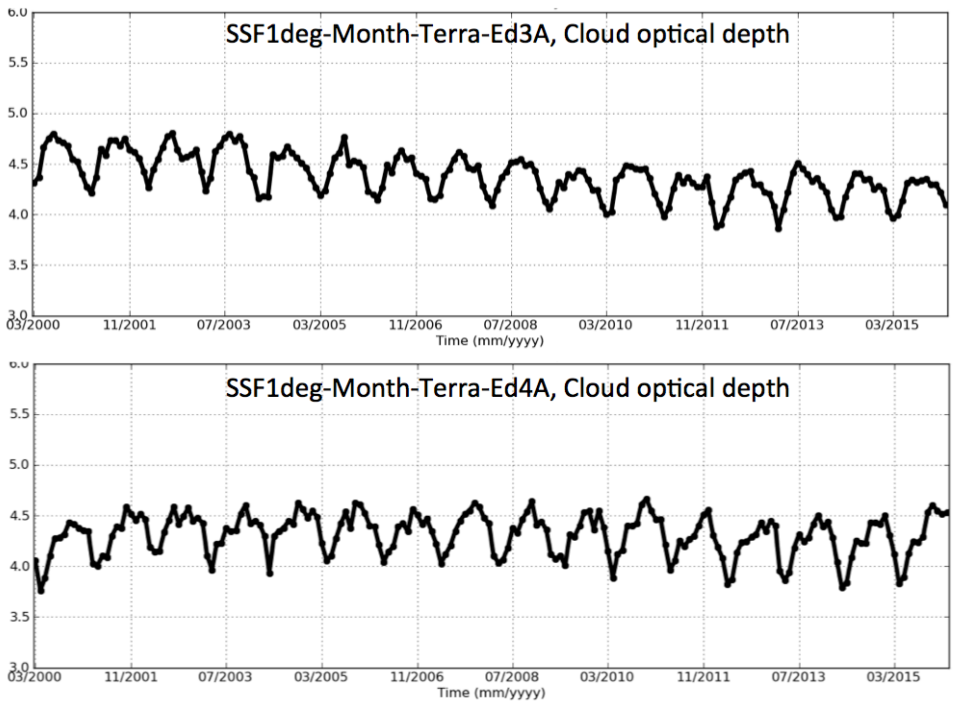


Figure 3-1. Comparison of the SSF1deg Terra-MODIS global monthly mean optical depth between Ed4A and Ed3A. Note the Terra-MODIS C5 calibration anomalies during 2003 and 2009 for Ed3A and were mitigated for Ed4A processing.

3.2.2 GEOS Versions

All CERES Edition 4A products are based upon consistent meteorological assimilated data (GEOS-5.4.1) throughout the record, whereas in Ed3A, GEOS-4 was replaced with GEOS-5.2 during January 2008 (see Table 3-1). The GEOS precipitable water (PW) showed a discontinuity in the Ed3A record due to the GEOS version transition (See Figure 3-2). Consistent use of the GEOS-5.4.1 atmosphere in Ed4A removes the discontinuity in the atmospheric profiles between versions.

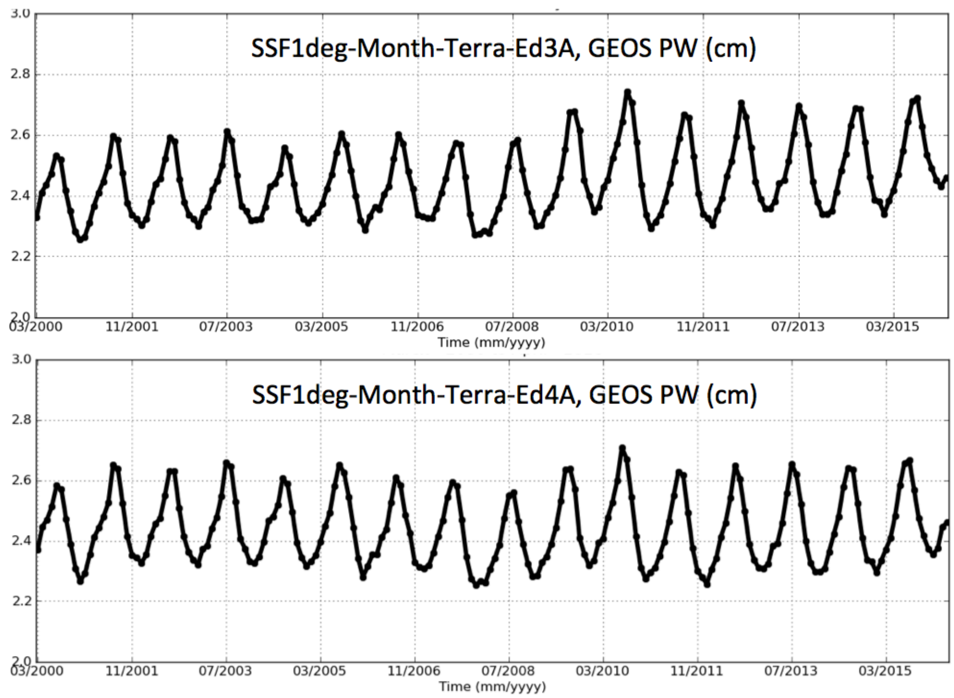


Figure 3-2. Comparison of the SSF1deg Terra global monthly mean precipitable (PW) anomalies between Ed4A and Ed3A using the CERES SSF1deg product. Note the Ed3A discontinuity during January 2008 coincides with the transition between GEOS-4.0 and GEOS-5.2. GEOS-5.4.1 has been used over the entire Ed4A record.

4.0 Accuracy and Validation

The primary goal of the CERES CldTypHist Ed4A products is to provide an Pc-Tau format dataset for the CERES SYN1deg Ed4A hourly retrieved MODIS or GEO cloud properties. The MODIS cloud retrievals were designed to be consistent across Terra and Aqua and over the record. This was accomplished by using similar channels between Terra and Aqua-MODIS and using consistent atmospheric profile dataset of GOES-5.4.2 and MODIS collection 5 over the record. The MODIS cloud property accuracy and validation can be found in the CERES Terra/Aqua Edition4A SSF DQS (link) and documented in Minnis et al. 2011.

The SYN1deg and CldTypHist GEO imager cloud properties were designed to be consistent with the MODIS retrievals. This consistency can be validated by comparing instantaneous GEO and MODIS coincident 1° gridded cloud properties. This validation has not been completed and will be added later to the DQS when it becomes available.

Section 4.1 validates the consistency between CldTypHist and SYN1deg total cloud properties. Consistency across data products is a CERES processing goal for Edition 4A. Section 4.2 discusses the SYN1deg Ed3A and Ed4A cloud property differences for each of the 5 GEO domains. The

4.1 Consistency between CldTypHist and SYN1deg clouds

The CERES CldTypHist Ed4A provides the combined Terra-MODIS, Aqua-MODIS, and GEO hourly cloud properties in the familiar Pc-Tau format. The SYN1deg product provides the same hourly cloud properties stratified into 4 cloud pressure layers to facilitate surface flux computations. The 4 pressure layers (Surface, 700mb, 500mb, 300mb, TOA) are not the same as the PC-Tau pressure layers of (Surface, 680mb, 440mb, TOA). In order to verify proper coding when assigning pixel level cloud properties to their respective cloud types, the cloud properties are summed over all cloud types to compute total cloud properties. The total cloud properties should be the same between CldTypHist and SYN1deg, except over 2-ch GEO domains. No night time optical depths are retrieved over GEO 2-ch domains. This precludes any GEO 2-ch night time clouds being incorporated into the CldTypHist product. CldTypHist does not temporally interpolate between GEO daytime and Terra and Aqua nighttime cloud retrievals to fill in the unobserved hourboxes. The SYN1deg Ed4A product does use the night time GEO 2-ch cloud properties and does temporally interpolate inbetween datagaps. Since the GEO data is retrieved hourly very few data gaps occur over non 2-ch GEO domains.

Figure 4-1 and Figure 4-2 display the CldTypHist minus SYN1deg cloud properties for January 2004 and July 2014. During January 2004, the 0°E, 60°E, and 140°E GEO domains were retrieved with 2-ch GEO cloud code, whereas during July 2014 only the 60°E position were based on 2-ch GEO cloud retreivals. These 2-ch GEO domains is where most of the GEO domain cloud differences occur. Note that over the non 2-ch GEO domains, there are very few cloud property differences. This validates that the pixel level cloud stratification code and total cloud averaging codes are consistent. Over the GOES East and West domains (75°W and 135°W) the scanning usually terminates at 50°S for scans that are not part of the 0,3,6, … GMT full disc (FD) scan sequence. For GOES East and West between 50° to 60° South, the hourly clouds were temporally interpolated in between the 3-hourly FD cloud retrievals (For example, see Figure 4-2 ice particle radius during July 2014). There are also small slivers inbetween GEO domains, where the CldTypHist and SYN1deg GEO domains were not assigned with the same GEO satellite. The CldTypHist product GEO domain encompasses ±59° in latitude, whereas the SYN1deg includes coverage between 60° to 62° in latitude depending on GEO domain. Most of the GEO boundary CldTypHist and SYN1deg inconsistencies have been resolved for data after January 2015.

The SYN1deg GEO 2-ch cloud night time amounts are usually less than during day, since both visible and IR channels can be used to detect clouds. The SYN1deg GEO 2-ch night time IR emissivity is assumed to be unity. During the day, the optical depth is used to infer the IR emissivity. Unlike the CldTypHist, the SYN1deg uses all of the GEO 2-channel hourly cloud properties to compute the monthly mean. The CldTypHist simply averages the daytime GEO 2-ch clouds with the MODIS day and night clouds. Also, the regional MODIS Ed4 cloud fractions in general are greater at night than during the day. This explains why over the GEO 2-ch domains the CldTypHist minus SYN1deg cloud fraction differences are usually positive, the cloud effective pressure is lower, and the IR emissivity is also lower.

The polar regions, outside of the GEO domain (60°S to 90°S and 60°N to 90°N) the CldTypHist minus SYN1deg differnces are due to Terra and Aqua cloud retrieval differences. No diurnal variations are expected over polar regions. The differences are more prominent over the South Pole, especially for cloud amount. They may also be a result of day and night MODIS retrieval differences, especially over Antarctica due to Terra and Aqua diurnal sampling time dependencies. The Terra and Aqua measurements overlap at during midnight and do not sample near local noon over Antarctica. Over the North Pole the Terra and Aqua measurements overlap during local noon and do not sample near midnight.

4.2 GEO domain cloud property consistency between Ed3A and Ed4A

4.2.1 GEO domain 15-year record day/night and Ed3A/Ed4A comparisons

The Ed3A cloud properties are based on the GEO 2-channel algorithm, whereas the Ed4A cloud properties took advantage of the additional GEO imagers to make the clouds more MODIS-like. With Edition 3A the night time cloud properties relied on a single IR channel. It assumed an IR emissivity of unity, did not correct the cloud hieght for non-black clouds. It also assumed a water and ice particle radii of 10µm and 30µm during both day and night, respectively, to compute the LWP and IWP. It must be noted that the SYN1deg product contains both the MODIS and GEO clouds. The Ed3A night time GEO domain mean cloud properties are shown in Table 4-1. As expected, the nighttime single IR channel based cloud amounts are less than the daytime, when both the visible and IR channels are used in the cloud mask. The nighttime IR emissivity is greater at night than during the day, as well as the effective and base cloud pressure, phase, ?? The daytime

GEO and nighttime MODIS optical depths are temporally interpolated. The night time optical depths are slightly smaller during the night. The water and ice particle radii are similar between day and night, since most of the measurements are from GEO, which assumed fixed particle sizes. The LWP and IWP, which are computed from particle radii and optical depth, are smaller at night, due to the lower nighttime optical depths.

The Ed4A GEO cloud properties are mostly a function of GEO imager quality and characteristics, such as number of channels and pixel resolution. The sequence of GEO imagers are listed in Figure 1-2. The number of GEO imager channels is listed Table 1-1. Some domains have GEO 2-ch at the beginning of the record, and GEO M-ch for the rest of the record. The 60° GEO domain has a GEO 2-ch over the entire record. It is very difficult to generalize the Ed4A cloud properties, shown Table 4-2, other than to say that the day and night cloud amounts are more consistent than for Ed3A. The optical depth, particle sizes, and LWP/IWP are greater during the day than at night, as are the Ed3A. The Ed4A IR emissivity was reduced at night compared to day, which is not the case for Ed3A. Similar to Ed3A the Ed4A the cloud effective pressure and base decreased and phase increased at night compared to day.

Comparing the Ed4A (Table 4-2) cloud properties with Ed3A (Table 4-1), the cloud fraction is larger overall by 1-5% and 4-14% for day and night, respectively. IR emissivity was reduced slightly for Ed4A. Comparison of the phase indicates that there more low clouds in Ed4A. Ed4A optical depth increased during the day and decreased at night. The LWP and IWP both increased between Ed4A compared to Ed3A.

4.2.2 GEO domain Ed3A/Ed4A total cloud trend analysis

Users were warned in Sections 1.0 and 2.0 (Caution and Helpful Hints), that when ever a GEO domain is crossed, whether in time or space, a slight change in mean cloud property values should be expected. In this section the monthly total cloud properties are monitored over time The total clouds are the cloud fraction wieghted cloud type cloud parameters. The discontinutities due to GEO satellite replacements within a sequence of satellite over a particular GEO domain. The GEO domain cloud differences may be real since each GEO domain encompasses an assortment of climate regimes.

Unlike Ed3A clouds that used a single GEO-2ch cloud retrieval code across all the GEO imagers in the CERES record, the Ed4A took advantage of the additional GEO channels of the 2nd generation GEOs. The most pronounced Ed4A GEO domain cloud property discontinuities is the transition between 1st and 2nd generation GEO satellites. For example, GMS-5 to GOES-9 (April 2003 over the 140°E Western Pacific domain) (see red line Figure 4-1 to Figure 4-4 right panel) and Met-7 to Met-8 (April 2004 over the 0°E Greenwich domain) (see blue line) for daytime cloud phase, liquid and ice particle phase, LWP, IWP and night time cloud fraction, IR emissivity, optical depth, liquid and ice particle size, LWP, IWP. The night time GEO 2-ch clouds assumed an IR emmisivity of 1, and fixed particle radii of 10µm and 30µm for water and ice, respectively.

Ed4A applied the MTSAT-1R visible channel point spread function, which reduced the cloud property discontinuities durint the transition of GOES-9 to MTSAT-2 compared with Ed3A. MTSAT-1R was operational between July 6, 2005 and July 1, 2010 (See

Table 2-3). The Ed3A MTSAT-1R daytime cloud amount (See red line Figure 4-1 and Figure 4-2 left panels), effective and base pressure, IR emissivity, phase, optical depth, and IWP. The MTSAT-1R PSF was applied in Ed4A and has mitigated the discontinutity surrounding the MTSAT-1R time period for the cloud properties. Greater differences (red line Right panels in Figure 4-1 and Figure 4-2) are due to the GMS-5 2-ch clouds prior to April 2003 and the GOES-9, MTSAT-1R, MTSAT-2 and Him-8 m-ch clouds after April 2003.

In general the GOES-West (135°W, black line) and GOES-East (75°W, yellow line) have the fewest discontinuities between the individual GEO records. This is because the 2nd generation GOES satellites encompassed the entire CERES record. This will change when GOES-16 (3rd generation) will replace GOES-13 in the GOES-East position in November 2017. The exception is the transition from GOES-8 to GOES-12 during April 2003. This was the first GOES satellite which replaced the 12µm channel with the 13.3 channel. Most of the night time cloud propeties show a discontinuitiy, especially IR emissivity, optical depth, and water and ice particle radii. A similar case can be made for the GOES-West (135°W) transition between GOES-11 (12µm) and GOES-15 (13.3µm) during December 2011

Over the Indian Ocean GEO domain (green line), the entire record is comprised of 1st generation Met-5 and Met-7 satellite. The Ed3A and Ed4A GEO 2-ch cloud retrieal algorithm is identical. However, the visible and IR calibration was updated between editions. The Ed4A calibration was tied to Aqua-MODIS the better characterized and more stable of the MODIS instruments. The 2008 to 2010 water and ice particle size and associated LWP and IWP discontinuity is not due to a GEO transition but due to a GEO domain boundary change during processing. Between 2008 and 2010 the west boundary was located at 28°E (the same used for Ed3A), for the rest of the years the west boundary was set at 41° (see Table 2-3). The GEO domain monthly cloud averages (Figure 4-1 to Figure 4-4) used fixed longitude boundaries. This discontinuity is not a result of cloud property differences, but of processing logistics. The Greenwich domain (blue line) shows the opposite discontintuity of the Indian Ocean domain (green line), which is expected.

The Meteosat-10 GEO m-ch cloud retrieval code was changed to improve accuracy for large optical depths, especially at night. The IR channels usually saturate for large optical depths and there for at night the optical depths are smaller than during the day. The Greenwich domain (blue line) in Jan 2013 shows a stark increase for optical depth, IR emissvity, particle size and LWP/IWP for both day and night. The first 3rd generation GEO satellite transitioned into the western Pacific domain during July 2015. The transition was rather uniform, except for water and ice particle size.

In general the Ed3A GEO domain cloud properties are more temporally stable then for Ed4A. However, the Ed4A clouds are probably more in line with MODIS, especially at night, in order to compute more accurate surface fluxes. The current plan for Edition 5 is to provide uniform cloud properties across GEO domains for the full CERES record and to provide a short term dataset that takes advantage of full constellation of 3rd generation

GEOs and 2nd generation Metoesats, that have channels similar to MODIS, in order to retrieve near MODIS-like clouds, merged with all available MODIS and VIIRS clouds onboard, Terra, Aqua, NPP, JPSS-1 beginning in 2019.

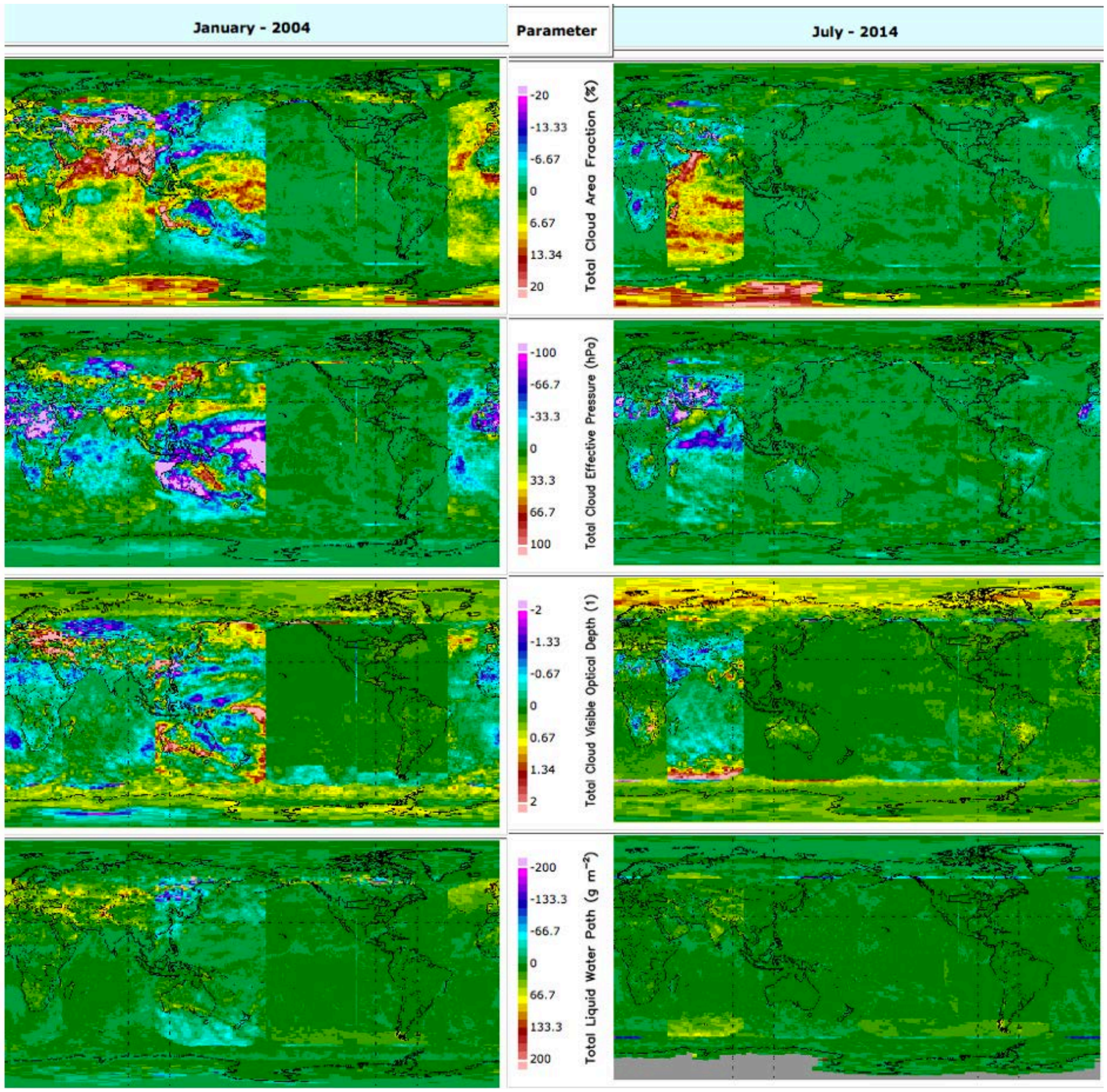


Figure 4-1. The CldTypHist Ed4A minus SYN1deg Ed4A total cloud fraction (%), effective pressure (mb), optical depth, and liquid water path (gm^{-2}). For January 2004 (left panels) and July 2014 (right panels).

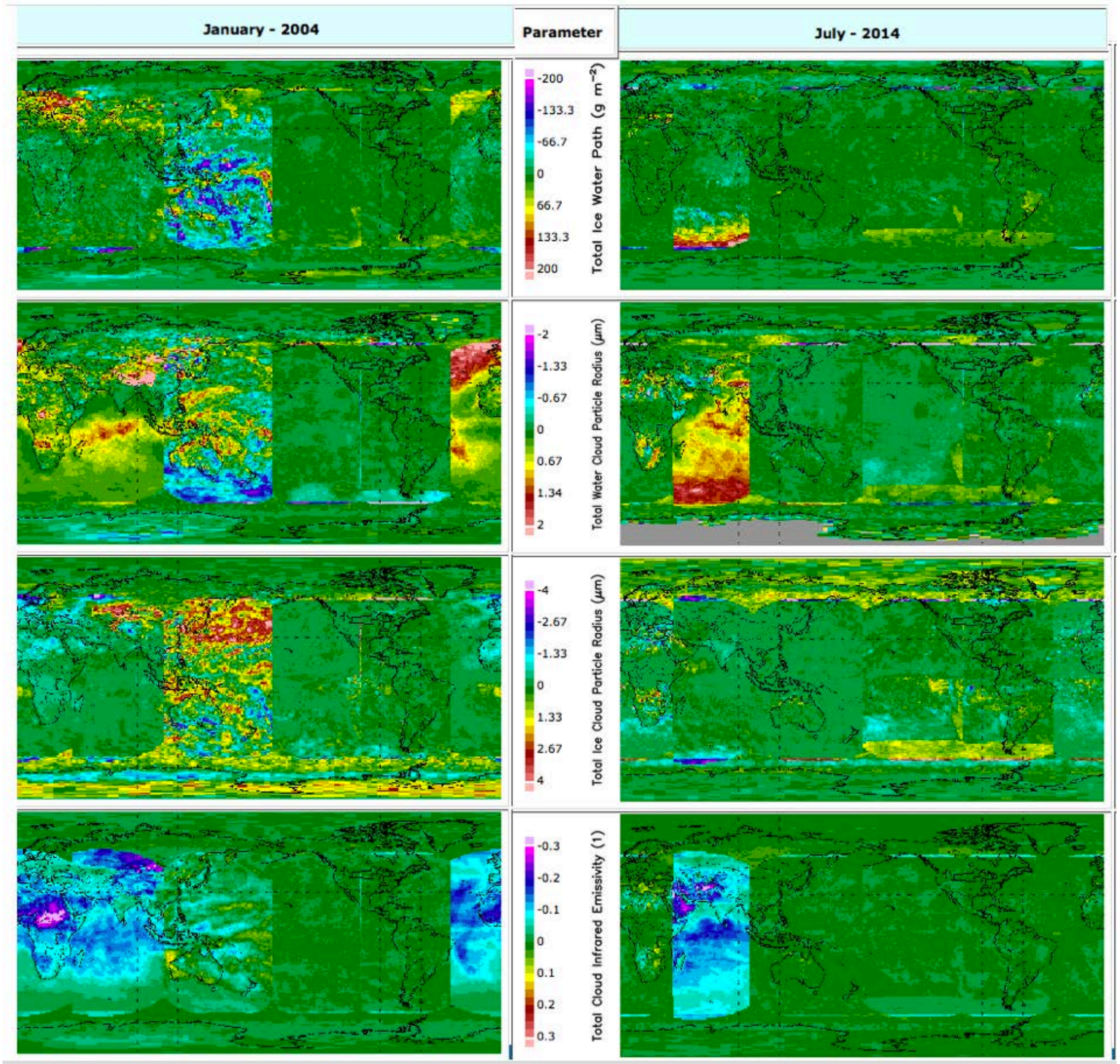


Figure 4-2. Same as Figure 4-1, except for ice water path (gm^{-2}), water particle radius (μm), ice particle radius (μm) and IR emissivity.

Table 4-1. The GEO domain averaged total cloud properties for the SYN1deg Ed3A product between March 2000 to February 2016.

	Day					Night				
Ed3 parameter	**0°**	**60°**	**140°**	**-135**	**-75**	**0°**	**60°**	**140°**	**-135**	**-75**
Cloud Fraction (%)	60	57	64	64	63	55	52	59	58	58
Eff Pressure (mb)	643	589	555	643	612	599	552	518	599	572
Base Pressure(mb)	716	659	629	717	687	668	619	585	665	640
IR Emissivity	0.86	0.86	0.87	0.87	0.88	0.91	0.91	0.90	0.90	0.91
Phase	1.42	1.51	1.56	1.43	1.48	1.42	1.49	1.54	1.42	1.46
Optical Depth	3.96	3.61	3.69	4.08	4.24	3.89	3.40	3.29	3.61	3.79
Water Radii (μm)	10.9	10.9	11.1	11.3	10.9	10.0	10.0	10.0	10.0	10.0
Ice Radii (μm)	28.3	28.6	28.9	28.9	28.7	29.9	29.9	29.9	29.9	29.9
LWP (gm-2)	43.2	41.4	42.7	41.8	46.4	39.8	35.0	35.0	34.0	40.0
IWP (gm-2)	165	152	155	180	167	96	88	87	96	91

Table 4-2. The GEO domain averaged total cloud properties for the SYN1deg Ed3A product between March 2000 to February 2016.

	Day					Night				
ED4 parameter	**0°**	**60°**	**140°**	**-135**	**-75**	**0°**	**60°**	**140°**	**-135**	**-75**
Cloud Fraction (%)	61	62	69	70	67	62	56	68	72	69
Eff Pressure (mb)	660	626	586	661	630	621	600	543	615	572
Base Pressure(mb)	757	703	693	767	743	704	672	630	694	660
IR Emissivity	0.85	0.84	0.83	0.84	0.86	0.84	0.91	0.78	0.77	0.80
Phase	1.31	1.44	1.42	1.28	1.31	1.32	1.34	1.43	1.33	1.38
Optical Depth	4.61	3.79	4.18	4.39	5.29	3.64	3.24	2.66	2.81	3.50
Water Radii (μm)	13.2	11.0	14.0	15.6	14.9	10.5	10.2	10.1	11.0	11.2
Ice Radii (μm)	28.3	29.6	29.0	28.6	28.0	25.2	28.5	26.7	24.6	22.5
LWP (gm-2)	87.0	51.2	95.0	101.8	115.1	60.6	39.7	40.7	41.6	53.5
IWP (gm-2)	252	205	255	277	308	106	110	108	82	87

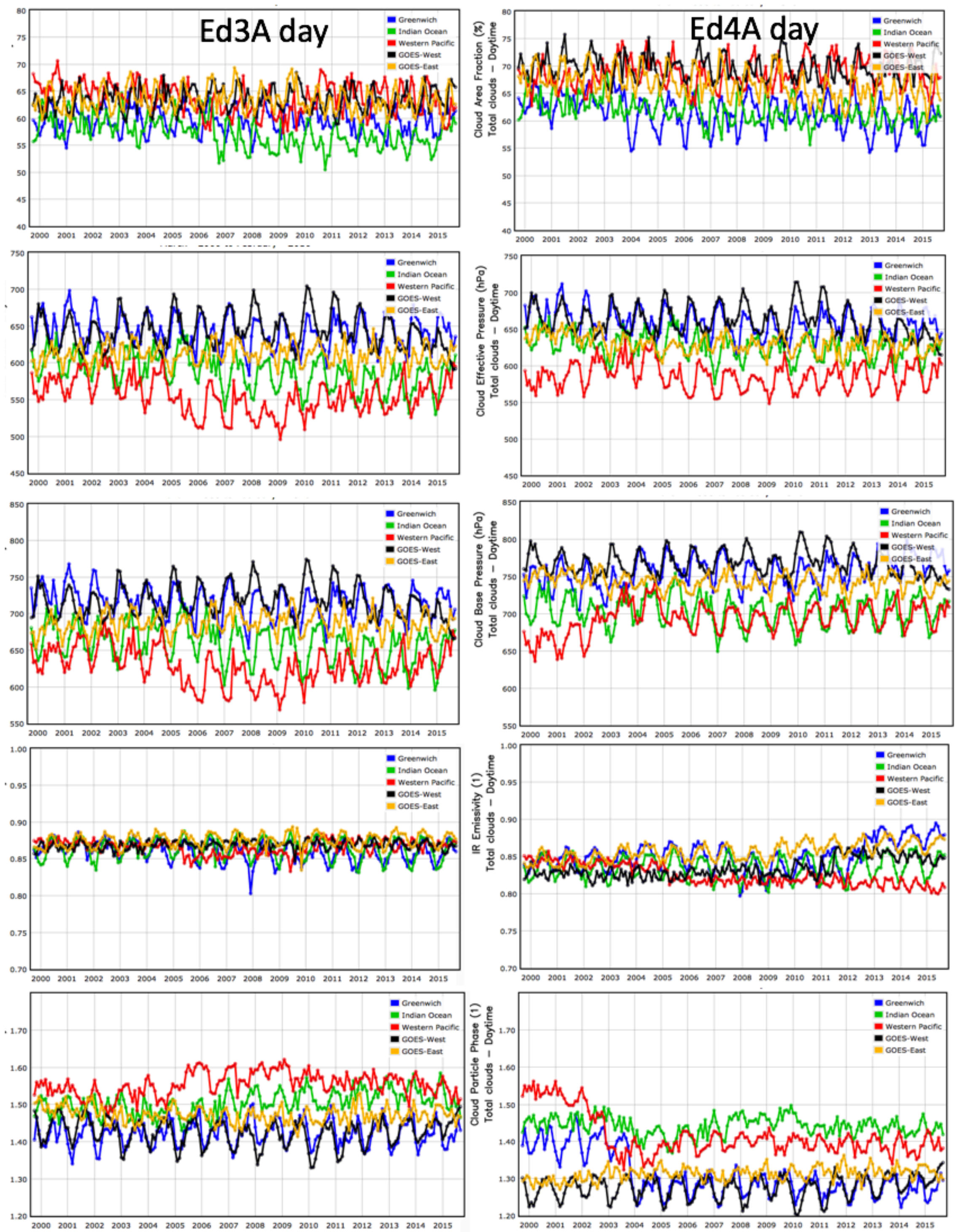


Figure 4-3. Comparison of the **daytime** SYN1deg Ed3A (left panels) and Ed4A (right panels) for the **total** cloud fraction, cloud effective pressure, cloud base pressure, IR emissivity, and cloud phase. The monthly averaged cloud properties during March 2000 and February 2016 between 60°S to 60°N as are shown as a function of GEO domain, 0°E (blue line), ~60°E (green line), 140°E (red line), 135°W (black line), and 75°W (yellow line). The cloud property ranges were held constant between day/night and Ed3/4

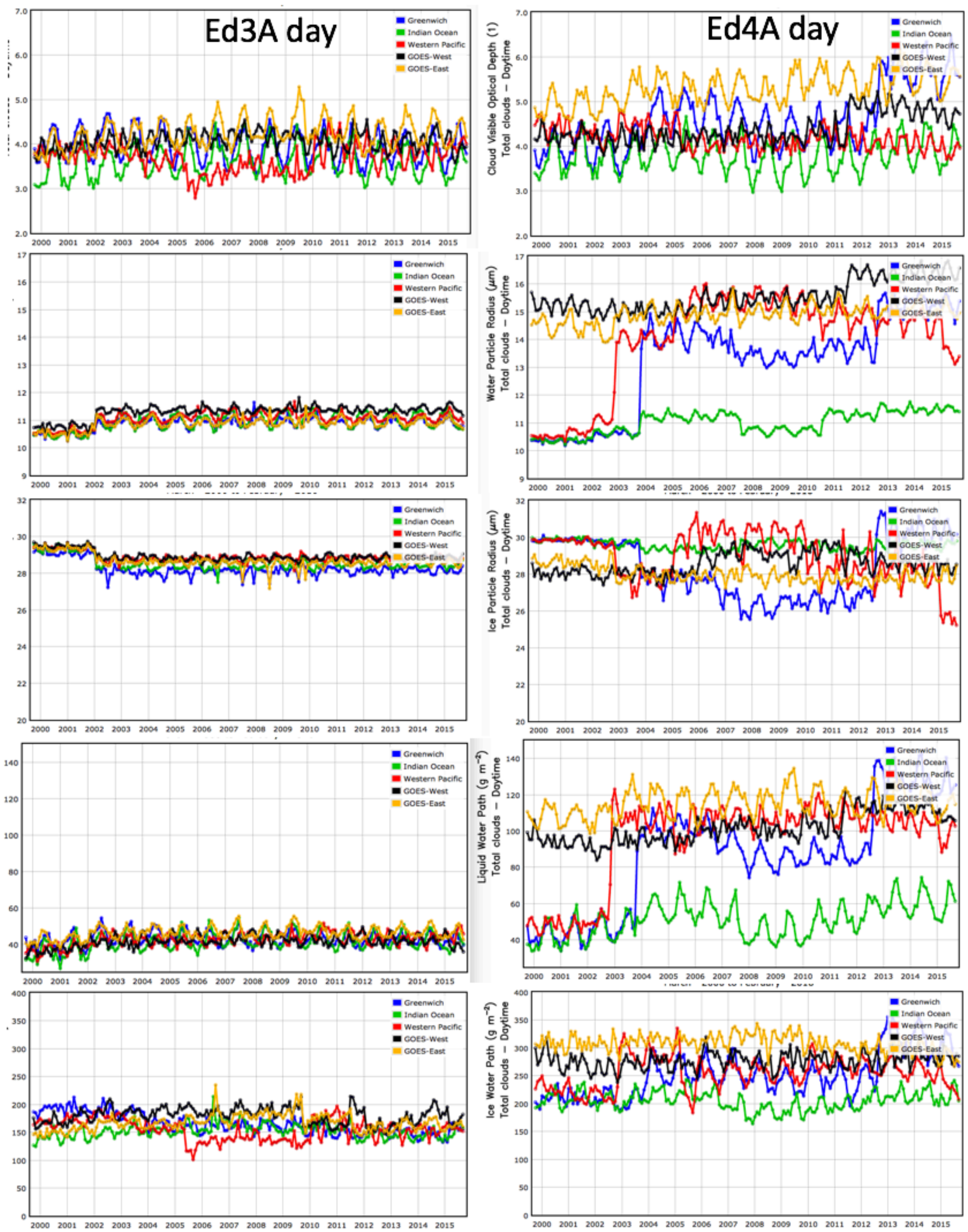


Figure 4-4. Same as Figure 4-1 except for the **daytime total** cloud visible optical depth, cloud water particle radii, cloud ice particle radii, liquid water path and ice water path.

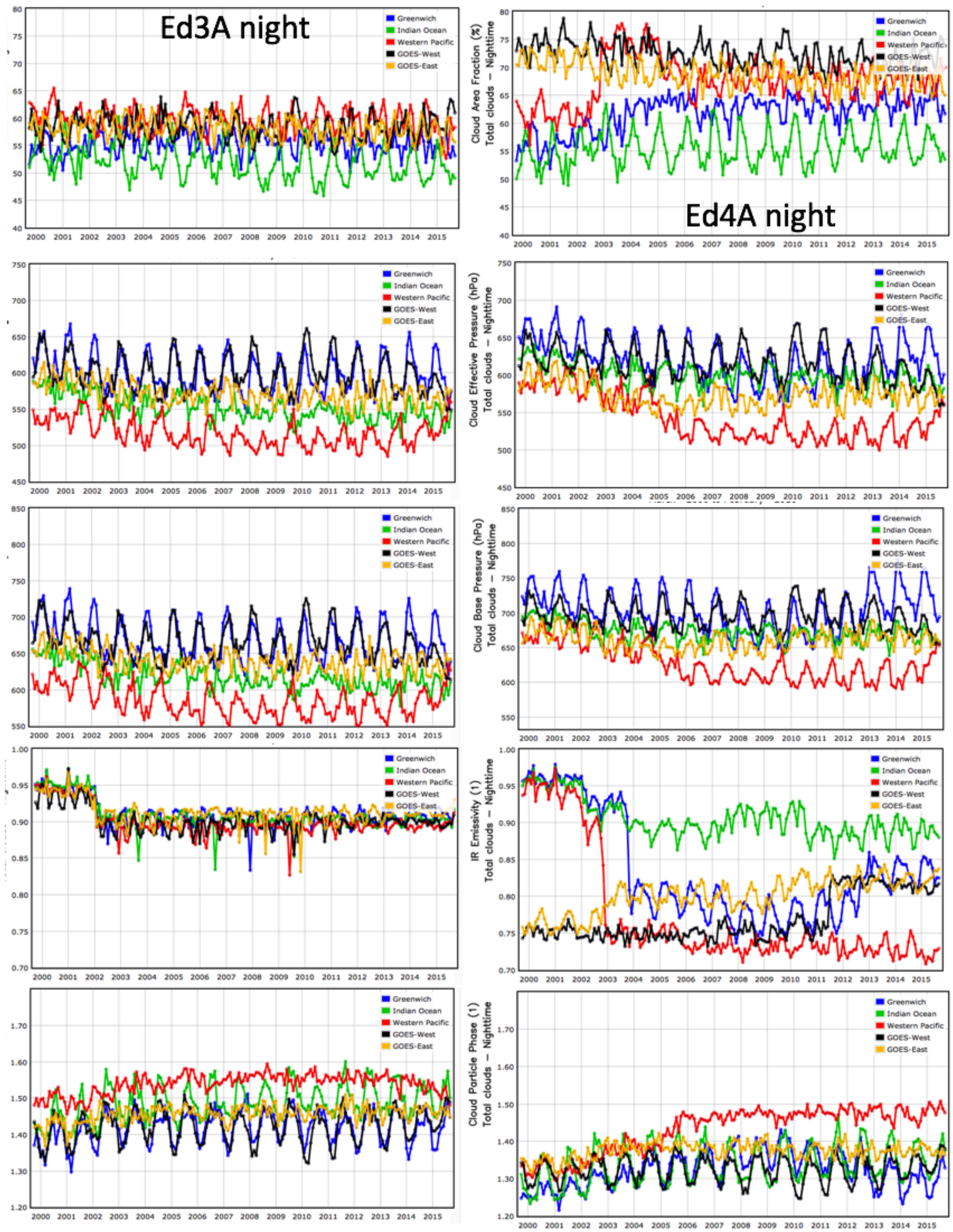


Figure 4-5. Figure 4-6. Same as Figure 4-1 except for the **night time total** cloud fraction, cloud effective pressure, cloud base pressure, IR emissivity, and cloud phase.

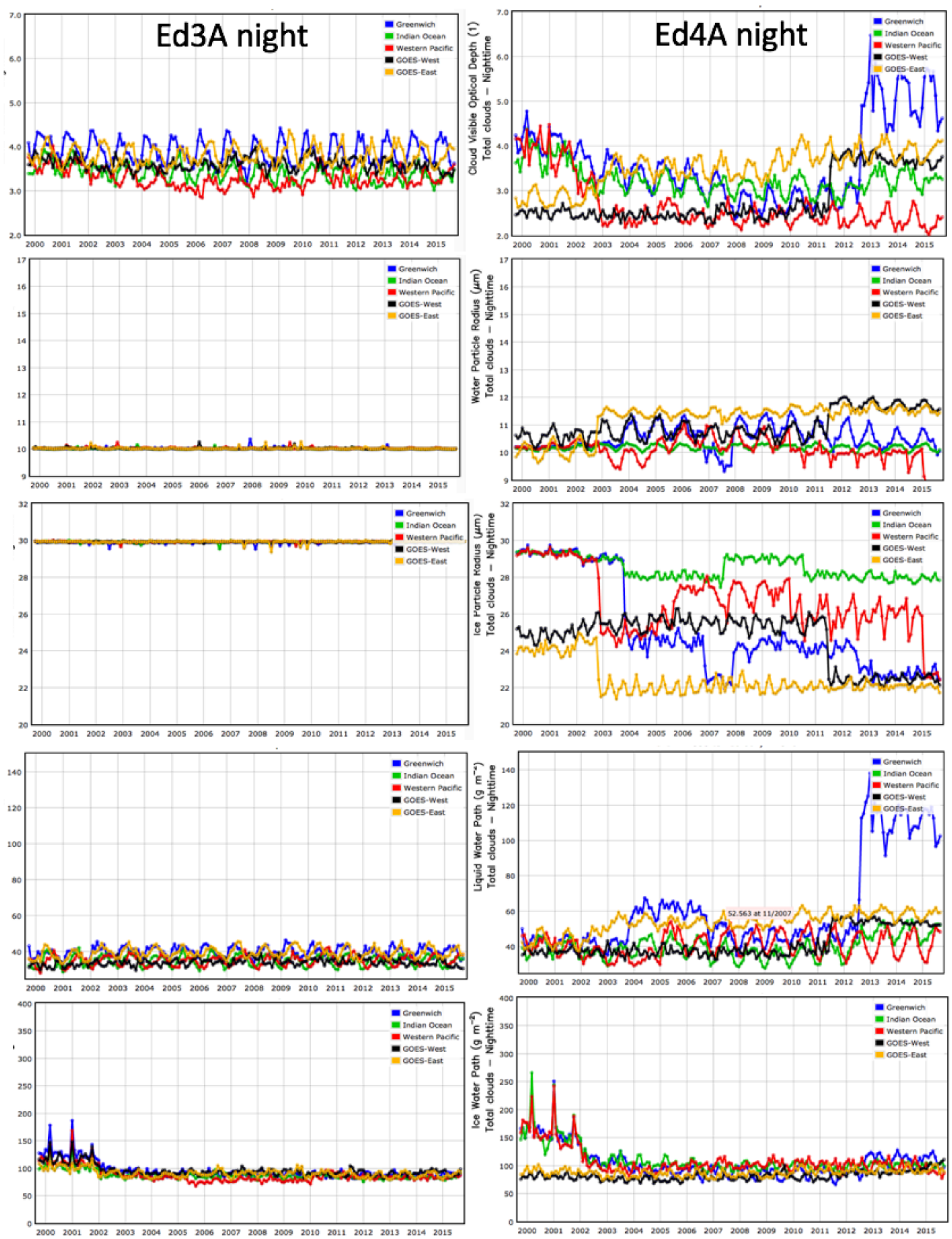


Figure 4-7. Same as Figure 4-1 except for the **night time total** cloud visible optical depth, cloud water particle radii, cloud ice particle radii, liquid water path and ice water path.

5.0 References

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6.0 Expected Reprocessing

There is no scheduled or planned reprocessing of the CldTypHist Ed4A product.

7.0 Attribution

When referring to the CERES CldTypHist Ed4A product, please include the product and data set version as: “CERES CldTypHist Ed4A.

The CERES Team has gone to considerable trouble to remove major errors and to verify the quality and accuracy of this data. Please provide a reference to the following paper when you publish scientific results with the

CERES CldTypHist Ed4A

Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee III, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment, Bull. Amer. Meteor. Soc., 77, 853-868.

When CERES data obtained via the CERES web site are used in a publiction, we request the following acknowledgment be included: “These data were obtained from the NASA Langley Research Center CERES ordering tool at http://ceres.larc.nasa.gov/.”

Please email ceres-help@lists.nasa.gov the citations of any published papers or reports that incorpoarte the use of data distributed by the CERES project.

When Langley ASDC data are used in a publication, we request the following acknowledgment be included: "These data were obtained from the NASA Langley Research Center EOSDIS Distributed Active Archive Center."

8.0 Feedback and Questions

For questions about or concerning the data and parameters ordered through the CERES subsetting/visualization/ordering tool http://ceres.larc.nasa.gov/order_data.php, please email ceres-help@lists.nasa.gov.

For comments involving the CERES CldTypHist Ed4A Data Quality Summary please email ceres-help@lists.nasa.gov.

For questions concerning data ordered at the Atmospheric Science Data Center (ASDC) https://eosweb.larc.nasa.gov/project/ceres/ceres_table contact the User and Data Services staff at the Atmospheric Science Data Center.